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(54) **MULTIVALENT PCV2 IMMUNOGENIC COMPOSITIONS AND METHODS OF PRODUCING SUCH COMPOSITIONS**

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(57) **ABSTRACT**

An improved method for recovering the protein expressed by open reading frame 2 from porcine circovirus type 2 is provided. Also provided is recombinant PCV2ORF2 protein, and immunogenic compositions comprising PCV2ORF2 protein. Moreover, multivalent combination vaccines are provided which include an immunological agent effective for reducing the incidence of or lessening the severity of PCV2 infection, preferably PCV2ORF2 protein, or an immunogenic composition comprising PCV2ORF2 protein, and at least one immunogenic active component of another disease-causing organism in swine.

11 Claims, 4 Drawing Sheets

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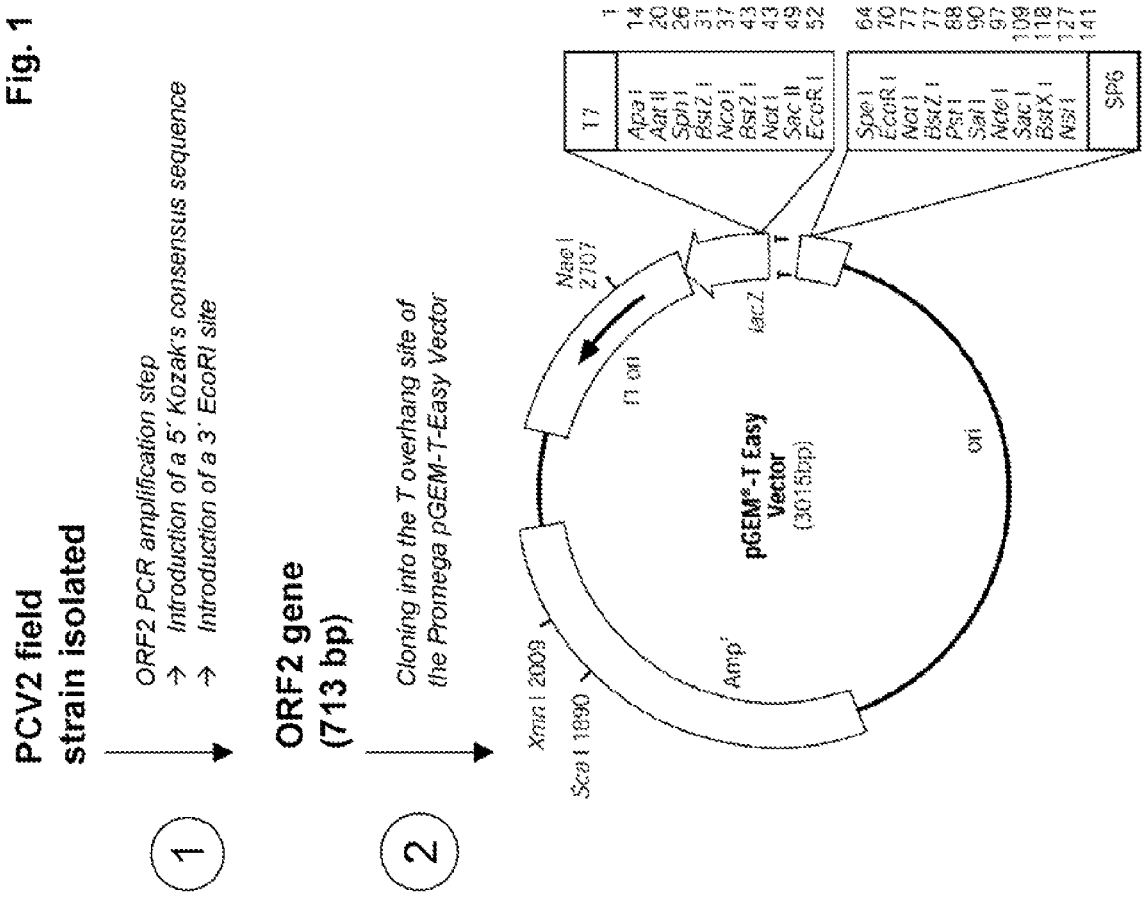
Fig. 1


PCV2 field strain isolated
1
ORF2 PCR amplification step
→ Introduction of a 5' Kozak's consensus sequence
→ Introduction of a 3' EcoRI site
ORF2 gene (713 bp)
2
Cloning into the T overhang site of the Promega pGEM-T-Easy Vector
Xmn I 2009
Sca I 1890
Amp'
pGEM®-T Easy Vector (3015bp)
f1 ori
Mae I 2707
lacZ
ori
T7
SP6
1 start
Apa I
Aat II
Sph I
BstZ I
Nco I
BstZ I
Not I
Sac II
EcoR I
Spe I
EcoR I
Not I
BstZ I
Pst I
Sal I
Nde I
Sac I
BstX I
Nsi I
Excision from pGEM-T-Easy at the Not I restriction site
3

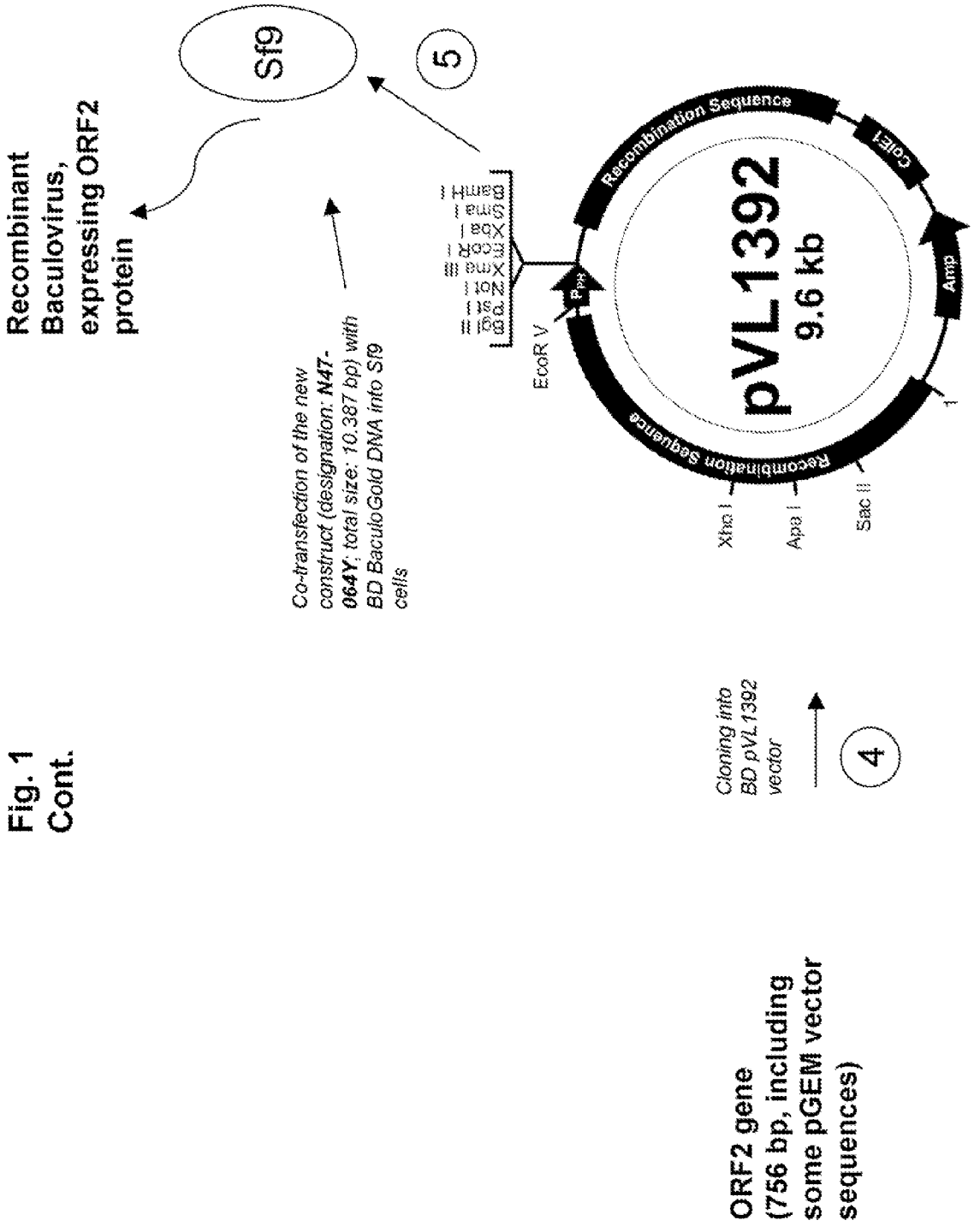

Recombinant Baculovirus, expressing ORF2 protein
Sf9
5
Co-transfection of the new construct (designation: N47-064Y; total size: 10.387 bp) with BD BaculoGold DNA into Sf9 cells
BamH I
Sma I
Xba I
EcoR I
Xma III
Not I
Sal I
Pst I
EcoR V
pVL1392
9.6 kb
Recombination Sequence
ColE1
Amp
Recombination Sequence
Xho I
Apa I
Sac II
Cloning into BD pVL1392 vector
4
ORF2 gene (756 bp, including some pGEM vector sequences)

Fig. 1
Cont.

FIG. 2(a)

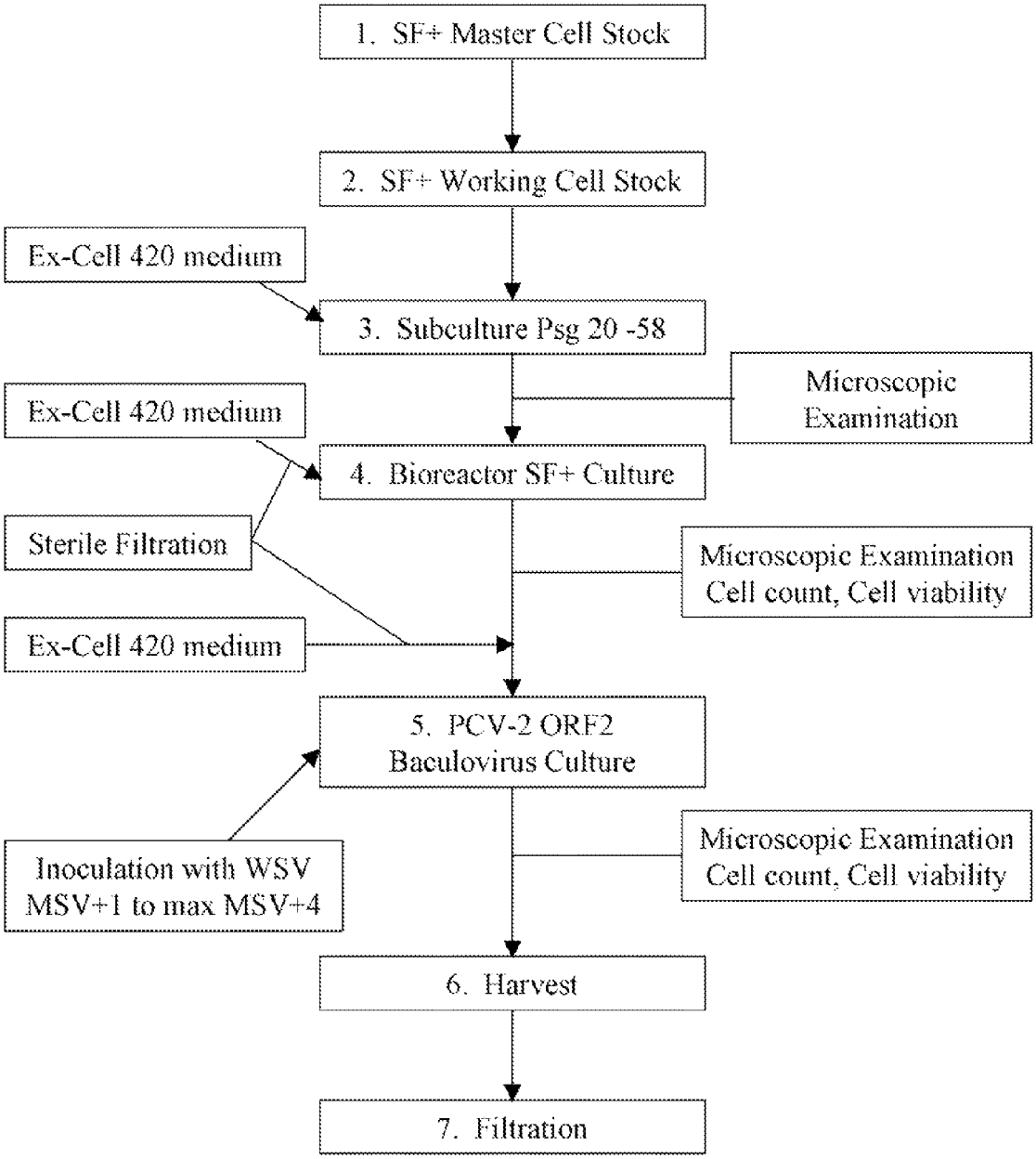
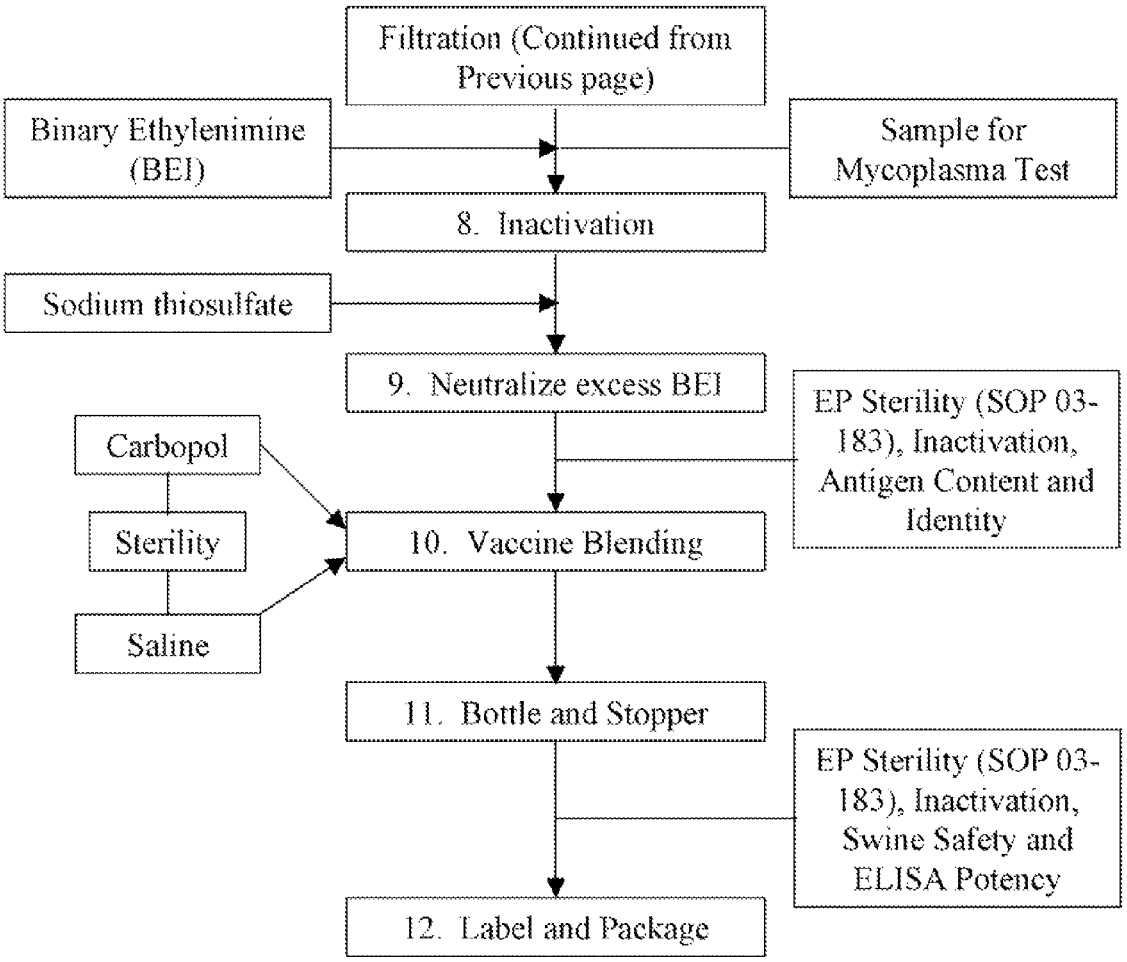

1. SF+ Master Cell Stock
2. SF+ Working Cell Stock
Ex-Cell 420 medium
3. Subculture Psg 20 -58
Microscopic Examination
Ex-Cell 420 medium
4. Bioreactor SF+ Culture
Sterile Filtration
Microscopic Examination Cell count, Cell viability
Ex-Cell 420 medium
5. PCV-2 ORF2 Baculovirus Culture
Inoculation with WSV MSV+1 to max MSV+4
Microscopic Examination Cell count, Cell viability
6. Harvest
7. Filtration

FIG. 2(b)


Filtration (Continued from Previous page)
Binary Ethylenimine (BEI)
Sample for Mycoplasma Test
8. Inactivation
Sodium thiosulfate
9. Neutralize excess BEI
EP Sterility (SOP 03-183), Inactivation, Antigen Content and Identity
Carbopol
Sterility
Saline
10. Vaccine Blending
11. Bottle and Stopper
EP Sterility (SOP 03-183), Inactivation, Swine Safety and ELISA Potency
12. Label and Package

MULTIVALENT PCV2 IMMUNOGENIC COMPOSITIONS AND METHODS OF PRODUCING SUCH COMPOSITIONS

RELATED APPLICATIONS

This application is a continuation of application Ser. No. 12/137,184, filed Jun. 11, 2008, which is a divisional of application Ser. No. 11/617,414, filed Dec. 28, 2006, now abandoned, which claims the benefit of provisional application Ser. No. 60/755,015, filed Dec. 29, 2005, the teachings and contents all of which are hereby incorporated by reference.

SEQUENCE LISTING

This application contains a sequence listing in paper format and in computer readable format, the teachings and content of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention

One aspect of the present invention is concerned with the recovery of a protein expressed by open reading frame 2 (ORF2) of porcine circovirus type 2 (PCV2). More particularly, the protein is a recombinant protein expressed by a transfected virus containing recombinant coding sequences for porcine circovirus type 2, open reading frame 2. Still more particularly, the transfected virus is permitted to infect cells in growth media and the protein expressed by open reading frame 2 is recovered in the supernate, rather than from inside the cells. Even more particularly, the method involves the steps of amplifying the open reading frame 2 gene from porcine circovirus type 2, cloning this amplified portion into a first vector, excising the open reading frame 2 portion from this first vector and cloning it into a transfer vector, cotransfecting the transfer vector with a viral vector into cells in growth media, causing the cells to become infected by the viral vector and thereby express open reading frame 2, and recovering the expressed recombinant protein coded for by open reading frame 2 in the supernate.

In another aspect, the present invention is concerned with an immunogenic composition effective for inducing an immune response against PCV2, and methods for producing those immunogenic compositions. More particularly, the present invention is concerned with an immunological composition effective for providing an immune response that protects an animal receiving the composition and reduces, or lessens the severity, of the clinical symptoms associated with PCV2 infection. Still more particularly, the present invention is concerned with a protein-based immunological composition that confers effective protection against infection by PCV2. Even more particularly, the present invention is concerned with an immunological composition comprising ORF2 of PCV2, wherein administration of PCV2-ORF2 results in protection against infection by PCV2. Most particularly, the present invention is concerned with an immunological composition effective for conferring effective immunity to a swine receiving the immunological composition, and wherein the composition comprises the protein expressed by ORF2 of PCV2.

In another aspect of the present invention, combination vaccines or multivalent vaccines are provided. More particularly, the present invention provides immunogenic compositions effective at inducing an immune response against infection by PCV2 and at least one other disease-causing organism for swine.

2. Description of the Prior Art

Porcine circovirus type 2 (PCV2) is a small (17-22 nm in diameter), icosahedral, non-enveloped DNA virus, which contains a single-stranded circular genome. PCV2 shares approximately 80% sequence identity with porcine circovirus type 1 (PCV1). However, in contrast with PCV1, which is generally non-virulent, swine infected with PCV2 exhibit a syndrome commonly referred to as Post-weaning Multisystemic Wasting Syndrome (PMWS). PMWS is clinically characterized by wasting, paleness of the skin, unthriftiness, respiratory distress, diarrhea, icterus, and jaundice. In some affected swine, a combination of all symptoms will be apparent while other swine will only have one or two of these symptoms. During necropsy, microscopic and macroscopic lesions also appear on multiple tissues and organs, with lymphoid organs being the most common site for lesions. A strong correlation has been observed between the amount of PCV2 nucleic acid or antigen and the severity of microscopic lymphoid lesions. Mortality rates for swine infected with PCV2 can approach 80%. In addition to PMWS, PCV2 has been associated with several other infections including pseudorabies, porcine reproductive and respiratory syndrome (PRRS), Glasser's disease, streptococcal meningitis, salmonellosis, postweaning colibacillosis, dietetic hepatosis, and suppurative bronchopneumonia.

Open reading frame 2 (ORF2) protein of PCV2, having an approximate molecular weight of 30 kDa when run on SDS-PAGE gel, has been utilized in the past as an antigenic component in vaccines for PCV2. Typical methods of obtaining ORF2 for use in such vaccines generally consist of amplifying the PCV2 DNA coding for ORF2, transfecting a viral vector with the ORF2 DNA, infecting cells with the viral vector containing the ORF2 DNA, permitting the virus to express ORF2 protein within the cell, and extracting the ORF2 protein from the cell via cell lysis. These procedures generally take up to about four days after infection of the cells by the viral vector. However, these procedures have a disadvantage in that the extraction procedures are both costly and time-consuming. Additionally, the amount of ORF2 recovered from the cells is not very high; consequently, a large number of cells need to be infected by a large number of viral vectors in order to obtain sufficient quantities of the recombinant expressed protein for use in vaccines and the like.

Current approaches to PCV2 immunization include DNA-based vaccines, such as those described in U.S. Pat. No. 6,703,023. However, such vaccines have been ineffective at conferring protective immunity against PCV2 infection and the clinical signs associated therewith.

Porcine Reproductive and Respiratory Syndrome (PRRS) is caused by a virus which was first isolated and classified as an arterivirus as recently as 1991. The disease syndrome had been first recognised in the USA in the mid 1980's and was called "mystery swine disease". It has also been called blue ear disease. The name porcine arterivirus has been proposed recently. The virus of PRRS has a particular affinity for the macrophages particularly those found in the lung. Macrophages are part of the body defenses. Those present in the lung are called alveolar macrophages. They ingest and remove invading bacteria and viruses but not in the case of the PRRS virus. Instead, the virus multiplies inside them producing more virus and kills the macrophages. Once it has entered a herd it tends to remain present and active indefinitely. Up to 40% of the macrophages are destroyed, which removes a major part of the bodies defense mechanism and allows bac-

teria and other viruses to proliferate and do damage. A common example of this is the noticeable increase in severity of enzootic pneumonia in grower/finisher units when they become infected with PRRS virus. It may take up to a year for all breeding stock, particularly in large herds, to become infected for the first time and although the virus appears to spread rapidly in a herd, it may be some 4-5 months before at least 90% of the sows have become sero-positive. Some sows remain naive. Furthermore, it is not uncommon for sow herds 1-2 years after infection to contain less than 20% of serological positive animals. This does not, however, necessarily mean they are not still immune nor does it mean that they have stopped passing on immunity to their offspring. Adult animals shed virus for much shorter periods of time (14 days) compared to growing pigs which can excrete it for 1-2 months. The clinical picture can vary tremendously from one herd to another. As a guide, for every three herds that are exposed to PRRS for the first time one will show no recognisable disease, the second would show mild disease, and the third moderate to severe disease. The reasons for this are not clearly understood. However the higher the health status of the herd, the less severe the disease effects. It may be that the virus is mutating as it multiplies, throwing up some strains that are highly virulent and some that are not. PRRS infects all types of herds, including high or ordinary health status and both indoor and outdoor units, irrespective of size.

Mycoplasma hyopneumoniae (M hyo) is a small bacterium (400-1200 nm) classified in the mycoplasmataceae family. M hyo is associated with Enzootic Pneumonia, a swine respiratory disease commonly seen in growing and finishing pigs. M hyo attacks the cilia of epithelial cells of the windpipe and lungs, causing the cilia to stop beating (ciliostasis) and eventually causing areas of the lungs to collapse. Depending on the extent of the disease, daily live weight gain of infected swine can be reduced by up to 17%. Enzootic Pneumonia is widespread in swine populations and present in almost every swine herd. M hyo is considered to be a primary pathogen that facilitates entry of PRRSV and other respiratory pathogens into the lungs. Three separate strains, 232, J & 7448, have had their genomes sequenced (Minion et al., J. Bacteriol. 186: 7123-33, 2004; Vasconcelos et al., J. Bacteriol. 187: 5568-77, 2005).

Porcine proliferative enteritis is a common diarrheal disease of growing-finishing and young breeding pigs characterized by hyperplasia and inflammation of the ileum and colon. It often is mild and self-limiting but sometimes causes persistent diarrhea, severe necrotic enteritis, or hemorrhagic enteritis with high mortality. The etiology is the recently classified intracellular bacterium *Lawsonia intracellularis*. The organism has been cultivated only in cell cultures, and attempts to propagate it in cell-free medium have failed. Koch's postulates have been fulfilled by inoculation of pure cultures of *L. intracellularis* into conventionally reared pigs; typical lesions of the disease were produced, and *L. intracellularis* was reisolated from the lesions. The more common, nonhemorrhagic form of the disease often affects 18- to 36-kg pigs and is characterized by sudden onset of diarrhea. The feces are watery to pasty, brownish, or faintly blood stained. After ~2 days, pigs may pass yellow fibrinonecrotic casts that have formed in the ileum. Most affected pigs recover spontaneously, but a significant number develop chronic necrotic enteritis with progressive emaciation. The hemorrhagic form is characterized by cutaneous pallor, weakness, and passage of hemorrhagic or black, tarry feces. Pregnant gilts may abort. Lesions may occur anywhere in the lower half of the small intestine, cecum, or colon but are most frequent and obvious in the ileum. The wall of the intestine is thickened, and the mesentery may be edematous. The mesenteric lymph nodes are enlarged. The intestinal mucosa appears thickened and rugose, may be covered with a brownish or yellow fibrinonecrotic membrane, and sometimes has petechial hemorrhages. Yellow necrotic casts may be found in the ileum or passing through the colon. Diffuse, complete mucosal necrosis in chronic cases causes the intestine to be rigid, resembling a garden hose. Proliferative mucosal lesions often are in the colon but are detected only by careful inspection at necropsy. In the profusely hemorrhagic form, there are red or black, tarry feces in the colon and clotted blood in the ileum.

Bovine Viral Diarrhoea Virus (BVD) and Border's Disease are two viruses, which are in the same group of pestiviruses as the virus of swine fever (hog cholera) but which primarily infect cattle and sheep respectively. They can get into pig breeding herds and cause reproductive problems. The disease is not a common cause of infertility in the sow and would be considered low on the list of possibilities from a diagnostic point of view.

Leptospirosis is a contagious disease of animals, including man, caused by various immunologically distinct leptospiral serovars, most of which are regarded as subgroups of *Leptospira interrogans*. There are five serovars and groups which are important in swine: *pomona, australis, tarassovi, canicola, icterohaemorrhagicae*, and *grippotyphosa*. Infections may be asymptomatic or cause various signs, including anorexia, pyrexia, listlessness, jaundice, abortions, stillbirths and other vague reproductive problems, and death. After acute infection, leptospires frequently localize in the kidneys or reproductive organs consisting of scattered small grey foci of a focal interstitial nephritis, and are shed in the urine, sometimes in large numbers for months or years. Because the organisms survive in surface waters for extended periods, the disease is often waterborne. In the USA, the disease is primarily due to the serovars *Leptospira hardjo, Leptospira pomona*, and *Leptospira grippotyphosa*. Diagnosis can be difficult because antibody titers can be transient, lasting less than a month. Further, *Leptospira* can also be found in healthy animals. *L. australis* serovar bratislava is most commonly associated with reproductive problems. Chronically infected herds display abortions, still births and weak piglets.

Brucellosis is caused by bacteria of the genus *Brucella* and is characterized by abortion, retained placenta, infertility, orchitis in boars, and severe metritis in sows. In piglets, the disease is characterized by posterior paralysis and lameness. The disease in pigs is caused almost exclusively by *Brucella suis* biovars 1, 2, and 3. A number of other mammals can carry and transmit *Brucella suis* to pigs. Infection spreads rapidly and causes many abortions in unvaccinated herds. Transmission occurs mainly by contact with another pig, although venereal transmission is possible. Serological diagnosis can be difficult due to a relatively common organism, *Yersinia enterocolitica* O:9 which shares a common antigen with *Brucella* and often causes false positive results. Post-mortem lesions usually include metritis and orchitis, and can include abscessation, sometimes with necorsis foci in the liver.

Clostridium is a ubiquitous gram-positive bacteria, of the family clostridiaceae, usually found in the soil, but also occurs naturally in the gut of most animals. *C. difficile* infections in swine are characterized by severe mesocolonic edema, diarrhea and edema in other tissues such as the hydrothorax. *Clostridium* enteritis in swine is caused by *C. perfringens*, and is characterized by chronic enteritis, which is accompanied by diarrhea, weight loss and fever. Infection with *C. perfringens* types A, B and C causes severe enteritis, dysentery, toxemia, and high mortality in young calves. Types B and C both produce the highly necrotizing and lethal β toxin

that is responsible for the severe intestinal damage. This toxin is sensitive to proteolytic enzymes, and disease is associated with inhibition of proteolysis in the intestine. Sow colostrum, which contains a trypsin inhibitor, has been suggested as a factor in the susceptibility of young piglets. The disease can cause sudden death in piglets less than one week old, and is most common within 3 days of birth. In older piglets, *Clostridium* enteritis causes a thickening of the small intestine making absorption of food and nutrients difficult. Piglets usually die as a result of a combination of the infection and lack of nutrients. Death may occur in a few hours, but less severe cases survive for a few days, and recovery over a period of several days is possible. Hemorrhagic enteritis with ulceration of the mucosa is the major lesion in all species. Grossly, the affected portion of the intestine is deep blue-purple and appears at first glance to be an infarction associated with mesenteric torsion. Smears of intestinal contents can be examined for large numbers of gram-positive, rod-shaped bacteria, and filtrates made for detection of toxin and subsequent identification by neutralization with specific antiserum.

Clostridium novyi has been suspected but not yet confirmed as a cause of sudden death in cattle and pigs fed high-level grain diets, and in which pre-existing lesions of the liver were not detectable. The lethal and necrotizing toxins (primarily α toxin) damage hepatic parenchyma, thereby permitting the bacteria to multiply and produce a lethal amount of toxin. Usually, death is sudden with no well-defined signs. Affected animals tend to lag behind the herd, assume sternal recumbency, and die within a few hours. Most cases occur in the summer and early fall when liver fluke infection is at its height. The disease is most prevalent in 1- to 4-yr-old sheep and is limited to animals infected with liver flukes. Differentiation from acute fascioliasis may be difficult, but peracute deaths of animals that show typical lesions on necropsy should arouse suspicion of infectious necrotic hepatitis. The most characteristic lesions are the grayish yellow necrotic foci in the liver that often follow the migratory tracks of the young flukes. Other common findings are an enlarged pericardial sac filled with straw-colored fluid, and excess fluid in the peritoneal and thoracic cavities. Usually, there is extensive rupture of the capillaries in the subcutaneous tissue, which causes the adjacent skin to turn black (hence the common name, black disease).

Clostridium septicum is found in soil and intestinal contents of animals (including man) throughout the world. Infection ordinarily occurs through contamination of wounds containing devitalized tissue, soil, or some other tissue-debilitant. Wounds caused by accident, castration, docking, insanitary vaccination, and parturition may become infected. General signs, such as anorexia, intoxication, and high fever, as well as local lesions, develop within a few hours to a few days after predisposing injury. The local lesions are soft swellings that pit on pressure and extend rapidly because of the formation of large quantities of exudate that infiltrates the subcutaneous and intramuscular connective tissue of the affected areas. Accumulations of gas are uncommon. Malignant edema associated with lacerations is characterized by marked edema, severe toxemia, and death in 24-48 hr.

Tetanus toxemia is caused by a specific neurotoxin produced by *Clostridium tetani* in necrotic tissue. Almost all mammals, including swine, are susceptible to this disease. Although tetanus is worldwide in distribution, there are some areas, such as the northern Rocky Mountain section of the USA, where the organism is rarely found in the soil and where tetanus is almost unknown. In general, the occurrence of *C. tetani* in the soil and the incidence of tetanus in man is higher in the warmer parts of the various continents. *Clostridium tetani*, an anaerobe with terminal, spherical spores, is found in soil and intestinal tracts. In most cases, it is introduced into the tissues through wounds, particularly deep puncture wounds, that provide a suitable anaerobic environment.

Infection with *Salmonella* spp can produce diarrhea in animals of all ages, especially those that are stressed, closely stocked, or exposed to a heavily contaminated feed or water supply. Salmonellosis is caused by many species of *salmonellae* and characterized clinically by one or more of three major syndromes—septicemia, acute enteritis, and chronic enteritis. The incidence has increased with the intensification of livestock production. Although various types of *Salmonella* can cause infections in pigs the classic *salmonellas* found in swine are *S. choleraesuis* and *S. typhimurium*. Their resulting clinical patterns of most *salmonella* are not distinct and different species of *salmonellae* tend to differ in their epidemiology. Plasmid profile and drug-resistance patterns are sometimes useful markers for epidemiologic studies. Septicemic salmonellosis is often associated with *S. choleraesuis*. Infected piglets demonstrate a reluctance to move, anorexia, a high fever of 40.5 C.-41.6 C., and may have a shallow cough. Piglets may also be found dead with cyanotic extremities. *S. choleraesuis* is one of the rare diseases that can cause both pneumonia and diarrhea and mortality of infected piglets is often high. Enterocolitis is generally associated with the more common *S. typhimurium*. Infections are characterized by yellow or watery diarrhea that may contain blood or mucus as the infection progresses. Mortality is low and often associated with dehydration and potassium deficiency from the diarrhea. Feces of infected animals can contaminate feed and water, fresh and processed meats from abattoirs, plant and animal products used as fertilizers or feedstuffs, pasture and rangeland, and many inert materials. Although *S. choleraesuis* is rarely found in feed. It can also be passed directly through contact with an infected animal. *Salmonella* can survive for months in wet, warm areas such as in feeder pig barns or in water dugouts. Rodents and wild birds also are sources of infection. The prevalence of infection varies among species and countries and is much higher than the incidence of clinical disease, which is commonly precipitated by stressful situations such as sudden deprivation of feed, transportation, drought, crowding, parturition, and the administration of some drugs.

Escherichia coli is a bacteria of the enterbacteriaceae family and is one of the main types of bacteria naturally occurring in the small intestines of all mammals. Although usually harmless, some *E. coli* strains can produce a number of exo- and endotoxins that cause infection and disease. Heat-labile (LT) and heat-stable (ST) exotoxins are actively produced by some strains and are responsible for causing scour. Shigela-like toxin type II variant (SLT-IIe), Stx2e and verotoxin edema disease act on the wall of the small arteries resulting in oedema. Endotoxins, such as Lipid A, play a role in mastitis and urinary tract infections. *E. coli* infection is characterized by a number of different symptoms depending on the particular strain involved, including diarrhea, sunken eyes, unthriftiness, visible weight loss, stunted growth, depression, bowel edema, mastitis, cystitis, pyelonephritis and death. *E. coli* can be classified and coded by their cell wall (O antigens) and fimbriae (F antigens). For example, scour is often associated with *E. coli* Abbotstown: O147, F4, F5, whereas bowel edema is associated with F18 fimbriae. Correctly identifying the code is essential to the selection of the correct vaccine. *E. coli* infections compromise a pig's immune system and deaths are often the result of secondary infections and disease.

Swine Pox is a disease which causes skin lesions, paules, pustules and scabs.

Eperythrozoonosis is a Rickettsial (haemotrophic) disease caused by *Eperythrozoon suis*, an extracellular bacterial organism that adheres to pig erythrocyte membranes, inducing its deformation and damage. The disease is characterized by anemia and icterus (yellow discoloration of mucous membranes, sclera and inner ears). It can lead to poor conception rates, other vague reproduction problems, and even death.

Hog cholera also known as Classical Swine Fever (CSF) or African Swine Fever (ASF) is a disease caused by a Flaviviridae virus, which is an enveloped RNA virus, or in the case of ASF, an enveloped DNA virus that is related to the Pox viruses. Clinically, CSF and ASF are indistinguishable. The first symptoms are a decrease in activity and drowsiness with some anorexia and the swine may appear chilled. Within days, pigs present with a marked fever (41-42 degrees Celsius), which is sometimes accompanied by a reddening of the skin. Next, pigs develop a conjunctivitis and constipation leading to yellowish diarrhea. In herds, the pigs will appear chilled and will often huddle together. A few pigs may convulse before dying. Pigs start to die with a spreading purple discoloration of the skin and death often occurs within 10-20 days post-infection. Surviving pigs will oftentimes be affected by a severe retardation of their growth and arched backs. In established herds, piglets infected from their mothers during pregnancy can result in abortion, mummification, malformations, still births and weak born piglets. Piglets born from CSF-infected mothers may remain healthy but continually spread the disease throughout their lives.

Pneumonic pasteurellosis and Streptococci are caused by *Pasteurella multocida* and various species of streptococci, typically *S. suis*. Infection by the causal agent generally represents the final stage of the post-weaning respiratory syndrome. Clinical signs appear in three forms, the acute form is most commonly associated with *P. multocida* serotype B. animals present with dyspnoea, labored breathing, thumping, high fever (42.2 Celsius), prostration, and finally death. In some cases the abdomen becomes purple with discoloration. A second form is a sub-acute form it is characterized by pleuritis, coughing, and difficulty in breathing. Pigs can loose significant amounts of weight and may have poor or no growth with serious consequences in pig flow. The chronic form presents with the occasional cough, thumping, and little or no fever. This form generally affects pigs from 10-16 weeks of age.

Streptococcal meningitis causes inflammation of the meninges which are the membranes covering the brain. In the sucking piglet it is usually caused by *Streptococcus suis, Haemophilus parasuis*, or sometimes bacteria such as *E. coli* and other streptococci. *S. suis* has many serotypes. In most countries *S. suis* type 1 is the main one in sucking piglets, but this may not be true in other countries. For example in Denmark it is type 7. *S. suis* also causes joint problems particularly types 1 and 14. *S. suis* is carried for long periods in the tonsils and may be transmitted to the sucking piglet from the sow or from other piglets. The sow also provides a variable level of immunity in the colostrum. Streptococcal meningitis in sucking piglets is sporadic in individual piglets. Streptococcal meningitis may be worse in sucking pigs when the organism has been introduced into the herd for the first time, or where it is secondary to infection with PRRS.

Pseudorabies, also known as porcine rabies virus, Suid herpes virus in which the causal agent is an enveloped herpes DNA virus. In naïve herds, neonatal pigs present with a range of severe central nervous signs from fitting to severe in coordination. Posterior paralysis may result in piglets sitting in a manner that resembles dogs. Additionally, mortality is high. In weaned pigs, the central nervous signs may be reduced but may be accompanied by an increase in respiratory signs. Oftentimes, respiratory diseases are associated with secondary infections. Weaned pigs can waste and suffer ill thrift and are often stunted. In growing pigs, the central nervous signs continue to reduce while the respiratory signs increase. The degree of respiratory disease depends on the presence and severity of secondary infections. In adults, reproductive signs predominate. Sows may abort and animals infected close to term are likely to give birth to stillborn or weak piglets. In established herds, there may be few clinical signs.

Swine Influenza Virus causes swine flu and belongs to the influenza Type A virus group. In naïve herds, clinical signs may present in explosive outbreaks with all or many animals becoming ill at the same time. Animals may present with inactivity, depression, huddling/pilling and anorexia. The animals are often mouth-breathing and breathing is labored. Coughing may ensue upon movement. Other clinical signs include a nasal discharge and puffy eyes with rectal temperatures between 40.5-41.5° Celsius. The high temperatures in a breeding stock can result in abortions, infertility, production of small weak litters, and increased still births. In established herds, annual reinfection appears.

Spirochaetal colitis is caused by the *Brachyspira pilosicoli* bacteria. This infection generally effects 10-20 week old growers/finishers. It is characterized by a non-fatal wasting diarrhea of growing pigs that results in an increased number of days needed to finish. The diarrhea also results in reduction in feed efficiency and produces watery diarrhea or loose stools. About half of the pigs may show transient to persist to watery to mucoid green to brownish diarrhea without blood. The clinical signs are more common 10-14 days after mixing and changing of the feed.

Swine dysentery is caused by the bacteria *Brachyspira hyodysentheriae*. There are twelve known sero-types at this time. Clinical signs in established herd include diarrhea, a rapid loss of condition in some pigs, a hairy appearance, dehydration, painful abdomen, and the death of one or two pigs before other pigs show any signs. In a key outbreak in naïve herds, all age groups from suckling piglets to adult sows can be effected.

Transmissible gastroenteritis is a disease of the intestines caused by a coronavirus. It is in the same family as porcine respiratory coronavirus, epidemic diarrhea virus, and hemagglutinating encephalomyelitis virus. Initial clinical signs are watery diarrhea, vomiting, and anorexia. Piglets less than 21 days of age generally die, weaners become unthrifty, while growers, finishers, and adults are generally mildly affected and will survive if provided with adequate water.

Parvovirus is a disease characterized by reproductive problems in pigs. The causal agent is a small DNA non-enveloped virus. Fetuses are the only affected group and the effect on the fetus depends upon the age at which it becomes infected. At 10-30 days of age, infection results in death and reabsorbtion of the fetus. Between 30-70 days of age, infection results in death and mummification. And from 70 days to term, infections results in the birth of weak piglets and mummification. The disease is able to cross the placenta and then move to each fetus along the uterus. In the sow, the clinical signs are still births, mummified piglets, embryonic deaths, infertility, and the production of a significantly reduced number of live-born offspring. Abortion is not a characteristic feature of parvovirus infection.

Actinobacillus pleuropneumonia, also known as APP and *Haemophilus pleuropneumonia*, is caused by the *Actinobacillus pleuopneumonia* bacteria. There are currently 15

serovirus described and the severity of the clinical signs differ between the different serovirus and the presence of other factors. Serovirus 1, 5, 9, 10, and 11 are considered to be more virulent. Additionally, serovirus 1, 9, and 11; 2, 6, and 8; and 4 and 7 may cross-react. Pigs of all ages are susceptible. Clinical signs are a sudden illness that results in animals lying down a lot and presenting a high rectal temperature of 41.5° Celsius. Animals are generally anorexic and do not drink, their extremities become cyanotic and cold to the touch. Cyanosis can spread to the whole body and severe breathing difficulties, often with mouth breathing, develop before death. Blood-stained froth can be seen at the mouth and nostrils and death generally occurs within 24-48 hours. Acute clinical signs include a high percentage of animals in a group being depressed and lying down, high rectal temperatures of 40.5-41° Celsius, anorexia, lack of drinking, severe respiratory distress, coughing, mouth breathing, cyanosis, vomiting, and abortion. Sub-acute clinical signs include intermittent coughing in a group of pigs, a general loss of appetite, and a reduction in growth. Cyrovar type 3 presents with arthritis, endocarditis, and abscesses. In chronically effected herds, daily weight gain may not be affected, but an intermittent cough may be heard.

Glässers Disease is caused by the bacterium *Haemophilus parasuis* (Hps), of which there are at least fifteen different types. It is found throughout the world and organisms are present even in high health herds. If such herds are set up using SPF or MEW techniques and are free from Hps, it can be devastating when they first become contaminated, producing an anthrax-like disease with high mortality in sows. In the majority of herds in which the bacterium is endemic, sows produce a strong maternal immunity which normally persists in their offspring until 8 to 12 weeks of age. As a result, the effects of the infection in weaners are usually nil or minimal. Disease may however be seen in suckling pigs. Pigs usually become sub-clinically infected when still protected by maternal antibody and then stimulate their own immune response. If however, the maternal immunity wears off before they become infected they may develop severe disease. This is usually sometime after weaning. It can also act as a secondary pathogen to other major diseases particularly enzootic pneumonia (EP) (*Mycoplasma hyopneumoniae*). Outbreaks of disease are sometimes experienced in sucking pigs, particularly in gilt herds. Hps attacks the smooth surfaces of the joints, coverings of the intestine, lungs, heart and brain causing pneumonia, heart sac infection, peritonitis and pleurisy. It is respiratory spread. Disease caused by Hps is rare in sows unless the dry sow is naïve. Lameness or stiffness, slight swellings over the joints and tendons, and rarely meningitis, are occasionally seen in gilts. In piglets, acute disease presents with rapidly depressed pigs with elevated temperature, inappetence, and a reluctance to rise. One characteristic feature is a short cough of 2-3 episodes. Sudden death in good sucking piglets is not uncommon Hps is also known to cause individual cases of arthritis and lameness with fever and inappetence. Chronic disease is characterized by pale and poor growing pigs. Sudden death may also occur. For weaners and growers, pigs with glässers disease become rapidly depressed or may be just found dead. Other symptoms include elevated temperature, anorexia, a reluctance to rise, nervous signs such as fits and convulsions including meningitis, and poor pigs, that are wasting and hairy often result. In young growing pigs, the following symptoms are most common: fever, mild meningitis, arthritis, lameness, pneumonia, heart sac infection, peritonitis and pleurisy. Again, a characteristic feature is a short cough of only 2-3 episodes.

Exudative epidermitis is caused by the bacterium *Staphylococcus hyicus* which lives normally on the skin without causing disease. It is not known why sometimes it flares up and causes a dermatitis which oozes greasy fluid. It produces toxins which are absorbed into the system and damage the liver and kidneys. In the sucking piglet disease is usually confined to individual animals, but it can be a major problem in new gilt herds and weaned pigs. During the days immediately preceding farrowing, the bacterium multiples profusely in the sow's vagina so that piglets are infected during the birth process or soon thereafter. Symptoms in sows include uncommon but localised lesions may be seen particularly behind the face and eyes. Severely affected piglets will die. In piglets, symptoms include localised lesions on the flanks and behind ears. Lesions usually commence with small, dark, localised areas of infection around the face or on the legs. The skin along the flanks the belly and between the legs changes to a brown color, gradually involving the whole of the body. The skin becomes wrinkled with flaking of large areas and it has a greasy feel. In severe cases, the skin turns black due to necrosis and the piglets die. A more localised picture is seen if the sow has passed some immunity to the piglet, with small circumscribed lesions approximately 5-10 mm in diameter that do not spread. For weaners and growers, symptoms usually commence about 3 days after weaning with localised, brown areas of infection or dermatitis around the face or on the legs, where the skin has been damaged. It may ulcerate. The skin along the flanks the belly and between the legs changes to a brown colour gradually involving the whole of the body. The skin becomes wrinkled with flaking of large areas and progresses to a dark greasy texture and in severe cases turns black. Such cases usually die due to the toxins produced by the staphylococci organisms. In nurseries up to 15% of the population may be involved and dehydration is common.

Swine erysipelas is caused by a bacterium, *Erysipelothrix rhusiopathiae* that is found in most if not all pig farms. Up to 50% of animals may carry it in their tonsils. It is always present in either the pig or in the environment because it is excreted via saliva, feces or urine. It is also found in many other species, including birds and sheep, and can survive outside the pig for a few weeks and longer in light soils. Thus it is impossible to eliminate it from a herd. Infected feces are probably the main source of infection, particularly in growing and finishing pens. The bacterium alone can cause the disease but concurrent virus infections, such as PRRS or influenza, may trigger off outbreaks. Disease is relatively uncommon in pigs under 8-12 weeks of age due to protection provided by maternal antibodies from the sow via the colostrum. The most susceptible animals are growing pigs, non vaccinated gilts, and up to 4th parity sows. The organism multiplies in the body, and invades the bloodstream to produce a septicaemia. The rapidity of multiplication and the level of immunity in the pig then determines the clinical symptoms.

Eperythrozoonosis (Epe) is a disease caused by a bacterium called *Eperythrozoonosis suis* which attaches to the surface of red blood cells and sometimes destroys them. The pig may then become anaemic and the products left after the destruction of the cells may cause jaundice. Clinical disease is more commonly seen in young growing pigs. However it can also cause reproductive problems in the breeding herd. A sow may carry Epe and yet remain quite healthy, however, it can cross the placenta resulting in weak pale pigs at birth. Epe is present in most if not all herds but the mechanisms which allow it to become pathogenic and produce disease in some populations and not in others are unknown. The incidence of disease is low.

Encephalomyocarditis, or EMC, infects and causes disease in a wide range of vertebrate animals but pigs appear to be the most susceptible of farm animal species. The virus is worldwide but differs in pathogenicity and virulence in different countries and regions. In most countries of Europe, particularly those in the EU, it tends to be relatively mild or non-pathogenic and disease in pigs is rarely diagnosed. In Australia the strains appear to be much more virulent for pigs than those in New Zealand. Virulent strains in Florida, the Caribbean and probably Central America damage the heart and cause death whereas those in the Mid West of the US tend to cause reproductive problems. Clinical disease in pigs tends to occur when rat numbers increase to plague levels. Pigs can be infected from rats or from rat-contaminated feed or water. It does not seem to spread very readily between pigs. In affected herds there are usually no clinical signs in weaned and growing pigs.

Aujeszky's disease, or AD, is an important disease of pigs caused by a herpes virus. The virus can remain hidden in nerves of the pig in a carrier state for long periods of time and then be reactivated. Once introduced into a herd, the virus usually remains there and it can continually affect reproductive performance at varying levels. The virus can survive for up to three weeks outside the pig. Acute outbreaks of disease occur when virulent strains of the virus first infect an unvaccinated susceptible herd. The virus crosses the uterus and placenta and infects the foetuses. The pig is the main host. However, dogs and cattle may also become infected, show nervous signs, and die.

Porcine Cytomegalovirus Infection (PCMV) is caused by a herpes virus found in the tissues throughout the body including the nose of newborn piglets where it causes inflammation (rhinitis). PCMV is present throughout the world and exists in most if not all pig populations but most infections are subclinical and clinical disease is rare. Serology carried out in the UK, for example, indicates that over 90% of herds have been exposed to infection. The rhinitis produced by this virus is uncommon and occurs mainly in newborn pigs and has no relationship to atrophic rhinitis caused by the toxin-producing bacteria *Pasteurella multocidia*. In most herds therefore the infection is insignificant and apart from sometimes causing a mild sneeze has no major effect on the health of the pig.

Blue Eye Disease is a viral disease that causes nervous symptoms, reproductive failure and opacity or blueing of the cornea. It is seen mainly in Mexico but has also been reported in other countries. It is not seen in Europe. Symptoms include inappetence, corneal opacity—conjunctivitis, nervous signs such as fits and convulsions, a tendency to sit like a dog, fever, increased returns, increased weaning to mating intervals, stillbirths, mummified piglets, high mortality in piglets, swollen testicles, and loss of libido.

Japanese B Encephalitis Virus (JE) is a virus spread by mosquitoes and is only important in countries where the insects are prevalent. Most domestic animals are affected. It causes an encephalitis in the human. The pig is an important source of infection. Symptoms include mummified or stillborn piglets, nervous signs in piglets such as fits and convulsions, and oedema fluid in piglets. It can also cause infertility and swollen testicles in boars.

Porcine Epidemic Diarrhoea (PED) is caused by a coronavirus somewhat similar to that which causes TGE. This virus is widespread in Europe. The virus damages the villi in the gut thus reducing the absorptive surface, with loss of fluid and dehydration. After introduction of the virus into a susceptible breeding herd, a strong immunity develops over two to three weeks. The colostral immunity then protects the piglets. The virus usually disappears spontaneously from breeding herds particularly small ones (<300 sows). Acute outbreaks of diarrhoea occur when the virus is first introduced into a susceptible population. In such cases up to 100% of sows may be affected, showing a mild to very watery diarrhoea. Two clinical pictures are recognised: PED Type I only affects growing pigs whereas PED Type II affects all ages including sucking pigs and mature sows. The incubation period is approximately 2 days and diarrhea lasts for 7 to 14 days. In sucking pigs, the disease can be mild or severe with mortalities up to 40%. In large breeding herds, particularly if kept extensively, not all the females may become infected first time around and there may be recrudescence. This only occurs in piglets suckling from sows with no maternal antibodies and is therefore sporadic.

Porcine Respiratory Corona Virus Infection (PRCV) first appeared in pigs in Europe some ten years or more ago. It is related to but distinct from TGE virus, which is another corona virus. It is thought to spread between farms on wind and so it is extremely difficult to keep herds free from it. Infection often takes place in the sucking pig at 2 to 3 weeks of age but is not of importance. It may have an effect on lung tissue when other respiratory pathogens are present in chronic respiratory disease complexes. Sows usually present no symptoms, but coughing may occur in the presence of other respiratory agents coughing may be associated. In piglets, a transient cough may be present. In weaners and growers, herds exposed for the first time have few if any signs of disease. The most common symptom is a transient coughing lasting only a few hours.

Rotavirus Infection is a virus infection that is widespread in pig populations. It is present in most if not all pig herds with virtually a 100% sero-conversion in adult stock. A further epidemiological feature is its persistence outside the pig where it is resistant to environmental changes and many disinfectants. Maternal antibodies persist for 3-6 weeks after which pigs become susceptible to infection but exposure does not necessarily result in disease. It is estimated that only 10-15% of diarrheas in pigs are initiated by a primary rotavirus infection. In a mature herd, disease appears after piglets are 7 to 10 days of age. It becomes progressively less important with age. However if pathogenic strains of *E. coli* are present, severe disease can occur with heavy mortality.

Rabies is caused by a virus and considered a rare disease in pigs. It is invariably fatal in all species including the human—hence its importance. Rabies is absent from the UK but present in may other countries throughout the world. Infection in piglets and sows is rare. In sows, weaners, and growers, the onset of disease is sudden with symptoms that include a nervous twitching of the face muscles, fits and convulsions, rapid chewing, salivation, muscles that may go into spasm, and posterior paralysis may occur. Death usually takes place within 3 days.

Swine Vesicular Disease (SVD) is a different virus from the virus that causes foot and mouth disease (FMD). However, it produces a disease in pigs that is clinically indistinguishable from FMD. This disease should always be considered if sudden widespread lameness appears with vesicles or blisters on the snout, tongue and tops of the claws.

Tuberculosis affects mammals, including people, birds, and swine. The causal organism, *Mycobacterium tuberculosis*, is sub-classified into types, human, bovine and avian. The avian type is referred to as *M. avium* or more often the avian/intracellulare complex because it is not a uniform species. *M. avium* itself infects mainly birds but is also found in the environment along with *M. intracellulare* which is predominantly saprophytic or free living. Pigs are rarely infected by the human or bovine types but are commonly infected by the

avian/intracellulare complex. The avian/intracellulare complex also causes sub-clinical non-progressive infection in healthy people. The main concern is that it could cause more serious disease in immuno-suppressed people and people with AIDS. In most countries if lesions are found in the neck at slaughter the whole head is condemned and if they are found in the mesenteric lymph nodes which drain the intestines the offals are condemned. If they are more widespread in the body, which is rare, the whole carcass may be condemned or cooked. If small lesions are missed by the meat inspector normal kitchen cooking destroys the organism. In all pigs, infection causes small nodules in the lymph nodes of the neck and those that drain the small intestine. In the great majority of cases the lesions are non-progressive, they do not spread through the body, do not make the pig ill and are not excreted. There are no clinical symptoms and there is no difference in performance between infected and non-infected pigs.

The virus of vesicular exanthema of swine (VES) is different from those causing foot-and-mouth disease (FMD) and swine vesicular disease (SVD) but it produces a disease in pigs that is clinically indistinguishable from FMD and SVD. Unlike FMD, it only effects pigs. Symptoms include low mortality, but there may be some deaths in suckling piglets. Other symptoms include salivation, inappetance, and vesicles around the mouth, nose, tongue and feet.

Vesicular Stomatitis (VS) causes a disease that occurs mainly in South and Central America, occasionally in the USA and rarely as epidemics extending as far North as Canada and as far South as Argentina. The VS virus produces a disease in pigs that is clinically indistinguishable FMD, SVD and VES. Most often however infection of pigs is subclinical. In all pigs, infection is characterized by drooling saliva, foot lesions and lameness, a reduction in growth rate, a rise in body temperature to 40-41° C. (106-107° F.) the appearance of vesicles (blisters) up to 30 mm diameter on the nose, lips, and teats and around the coronets of the feet which may make the pigs lame. Mortality is usually low and most pigs recover in one to two weeks.

Atrophic Rhinitis, Progressive and Unprogressive Disease which causes inflammation of the nose and it can be caused by a variety of bacteria and irritant substances. During the process of infection, the delicate structures or turbinate bones in the nose become damaged and atrophy or disappear. Progressive atrophic rhinitis describes a specific disease where the nose tissues permanently atrophy. It is caused by specific toxin producing strains of *Pasteurella multocidia* (PMt). There are two types A and D. In sucking pigs, sneezing, snuffling and a nasal discharge are the first symptoms, but in acute outbreaks where there is little maternal antibody, the rhinitis may be so severe to the extent that there is hemorrhage from the nose. By three to four weeks of age and from weaning onwards, there is evidence of tear staining and malformation of the nose associated with twisting and shortening. Severely affected pigs may have problems eating. There is considerably reduced daily gain. In severe outbreaks pigs may not grow to market weight.

Eastern equine encephalomyelitis viruses (EEEV) are members of the Alphavirus genus, family Togaviridae. EEEV can be transmitted to equines and humans during the bite of an infected mosquito. In addition to horses and humans, EEEV can produce severe disease in common livestock species such as swine and cattle. EEEV, or virus-specific antibodies, have been recovered from birds such as the turkey, pheasant, quail, ostrich, and emu, among others.

Mycoplasma arthritis is caused by *Mycoplasma hyosynoviae* infection. This arthritis, is characterized by inflammation of one or more joints and is common in all sucking and growing pigs and sows. However, it is rare in piglets.

Infection in swine is also caused by adenovirus and hemagglutinating encephalomyelitis virus.

Accordingly, what is needed in the art is a method of obtaining ORF2 protein, which does not require extraction of the ORF2 protein from within infected cells. What is further needed are methods of obtaining recombinant ORF2 protein in quantities sufficient for efficiently preparing vaccine compositions. What is still further needed are methods for obtaining ORF2 protein which do not require the complicated and labor-intensive methods required by the current ORF2 protein extraction protocols. Finally, with respect to compositions, what is needed in the art is an immunogenic composition which does confer protective immunity against PCV2 infection and lessens the severity of or prevents the clinical signs associated therewith.

SUMMARY OF THE INVENTION

The present invention overcomes the problems inherent in the prior art and provides a distinct advance in the state of the art. Specifically, one aspect of the present invention provides improved methods of producing and/or recovering recombinant PCV2 ORF2 protein, i) by permitting infection of susceptible cells in culture with a recombinant viral vector containing PCV2 ORF2 DNA coding sequences, wherein ORF2 protein is expressed by the recombinant viral vector, and ii) thereafter recovering the ORF2 in the supernate. It has been unexpectedly discovered that ORF2 is released into the supernate in large quantities if the infection and subsequent incubation of the infected cells is allowed to progress past the typical prior PCV 2 ORF2 recovery process, which extracts the PCV2 ORF2 from within cells. It furthermore has been surprisingly found, that PCV ORF2 protein is robust against prototypical degradation outside of the production cells. Both findings together allow a recovery of high amounts of PCV2 ORF2 protein from the supernate of cell cultures infected with recombinant viral vectors containing a PCV2 ORF2 DNA and expressing the PCV2 ORF2 protein. High amounts of PCV2 ORF2 protein means more than about 20 μg/mL supernate, preferably more than about 25 μg/mL, even more preferably more than about 30 μg/mL, even more preferably more than about 40 μg/mL, even more preferably more than about 50 μg/mL, even more preferably more than about 60 μg/mL, even more preferably more than about 80 μg/mL, even more preferably more than about 100 μg/mL, even more preferably more than about 150 μg/mL, most preferably than about 190 μg/mL. Those expression rates can also be achieved for example by the methods as described in Examples 1 to 3.

Preferred cell cultures have a cell count between about $0.3–2.0\times10^6$ cells/mL, more preferably from about $0.35–1.9\times10^6$ cells/mL, still more preferably from about $0.4–1.8\times10^6$ cells/mL, even more preferably from about $0.45–1.7\times10^6$ cells/mL, and most preferably from about $0.5–1.5\times10^6$ cells/mL. Preferred cells are determinable by those of skill in the art. Preferred cells are those susceptible for infection with an appropriate recombinant viral vector, containing a PCV2 ORF2 DNA and expressing the PCV2 ORF2 protein. Preferably the cells are insect cells, and more preferably, they include the insect cells sold under the trademark Sf+ insect cells (Protein Sciences Corporation, Meriden, Conn.). Appropriate growth media will also be determinable by those of skill in the art with a preferred growth media being serum-free insect cell media such as Excell 420 (JRH Biosciences, Inc., Lenexa, Kans.) and the like. Preferred viral vectors

include baculovirus such as BaculoGold (BD Biosciences Pharmingen, San Diego, Calif.), in particular if the production cells are insect cells. Although the baculovirus expression system is preferred, it is understood by those of skill in the art that other expression systems will work for purposes of the present invention, namely the expression of PCV2 ORF2 into the supernatant of a cell culture. Such other expression systems may require the use of a signal sequence in order to cause ORF2 expression into the media. It has been surprisingly discovered that when ORF2 is produced by a baculovirus expression system, it does not require any signal sequence or further modification to cause expression of ORF2 into the media. It is believed that this protein can independently form virus-like particles (Journal of General Virology Vol. 81, pp. 2281-2287 (2000) and be secreted into the culture supernate. The recombinant viral vector containing the PCV2 ORF2 DNA sequences has a preferred multiplicity of infection (MOI) of between about 0.03-1.5, more preferably from about 0.05-1.3, still more preferably from about 0.09-1.1, and most preferably from about 0.1-1.0, when used for the infection of the susceptible cells. Preferably the MOIs mentioned above relates to one mL of cell culture fluid. Preferably, the method described herein comprises the infection of 0.35–1.9×10^6 cells/mL, still more preferably of about 0.4–1.8×10^6 cells/mL, even more preferably of about 0.45–1.7×10^6 cells/mL, and most preferably of about 0.5–1.5×10^6 cells/mL with a recombinant viral vector containing a PCV2 ORF2 DNA and expressing the PCV2 ORF protein having a MOI (multiplicity of infection) of between about 0.03-1.5, more preferably from about 0.05-1.3, still more preferably from about 0.09-1.1, and most preferably from about 0.1-1.0.

The infected cells are then incubated over a period of up to ten days, more preferably from about two days to about ten days, still more preferably from about four days to about nine days, and most preferably from about five days to about eight days. Preferred incubation conditions include a temperature between about 22-32° C., more preferably from about 24-30° C., still more preferably from about 25-29° C., even more preferably from about 26-28° C., and most preferably about 27° C. Preferably, the Sf+ cells are observed following inoculation for characteristic baculovirus-induced changes. Such observation may include monitoring cell density trends and the decrease in viability during the post-infection period. It was found that peak viral titer is observed 3-5 days after infection and peak ORF2 release from the cells into the supernate is obtained between days 5 and 8, and/or when cell viability decreases to less than 10%.

Thus, one aspect of the present invention provides an improved method of producing and/or recovering recombinant PCV2 ORF2 protein, preferably in amounts described above, by i) permitting infection of a number of susceptible cells (see above) in culture with a recombinant viral vector with a MOI as defined above, ii) expressing PCV2 ORF2 protein by the recombinant viral vector, and iii) thereafter recovering the PCV2 ORF2 in the supernate of cells obtained between days 5 and 8 after infection and/or cell viability decreases to less then 10%. Preferably, the recombinant viral vector is a recombinant baculovirus containing PCV2 ORF2 DNA coding sequences and the cells are Sf+ cells. Additionally, it is preferred that the culture be periodically examined for macroscopic and microscopic evidence of contamination or for atypical changes in cell morphology during the post-infection period. Any culture exhibiting any contamination should be discarded. Preferably, the expressed ORF2 recombinant protein is secreted by the cells into the surrounding growth media that maintains cell viability. The ORF2 is then recovered in the supernate surrounding the cells rather than from the cells themselves.

The recovery process preferably begins with the separation of cell debris from the expressed ORF2 in media via a separation step. Preferred separation steps include filtration, centrifugation at speeds up to about 20,000×g, continuous flow centrifugation, chromatographic separation using ion exchange or gel filtration, and conventional immunoaffinity methods. Those methods are known to persons skilled in the art for example by (Harris and Angel (eds.), Protein purification methods—a practical approach, IRL press Oxford 1995). The most preferred separation methods include centrifugation at speeds up to about 20,000×g and filtration. Preferred filtration methods include dead-end microfiltration and tangential flow (or cross flow) filtration including hollow fiber filtration dead-end micro filtration. Of these, dead-end microfiltration is preferred. Preferred pore sizes for dead-end microfiltration are between about 0.30-1.35 μm, more preferably between about 0.35-1.25 μm, still more preferably between about 0.40-1.10 μm, and most preferably between about 0.45-1.0 μm. It is believed that any conventional filtration membrane will work for purposes of the present invention and polyethersulfone membranes are preferred. Any low weight nucleic acid species are removed during the filtration step.

Thus, one further aspect of the present invention provides an improved method of producing and/or recovering recombinant PCV2 ORF2 protein, preferably in amounts described above, by i) permitting infection of a number of susceptible cells (see above) in culture with a recombinant viral vector with a MOI as defined above, ii) expressing PCV ORF2 protein by the recombinant viral vector, iii) recovering the PCV2 ORF2 in the supernate of cells obtained between days 5 and 8 after infection and/or cell viability decreases to less then 10%, and, iv) separating cell debris from the expressed PCV2 ORF2 via a separation step. Preferably, the recombinant viral vector is a baculovirus containing ORF2 DNA coding sequences and the cells are SF+ cells. Preferred separation steps are those described above. Most preferred is a dead-end microfiltration using a membrane having a pore size between about 0.30-1.35 μm, more preferably between about 0.35-1.25 μm, still more preferably between about 0.40-1.10 μm, and most preferably between about 0.45-1.0 μM.

For recovery of PCV2 ORF2 that will be used in an immunogenic or immunological composition such as a vaccine, the inclusion of an inactivation step is preferred in order to inactivate the viral vector. An "immunogenic or immunological composition" refers to a composition of matter that comprises at least one antigen which elicits an immunological response in the host of a cellular and/or antibody-mediated immune response to the composition or vaccine of interest. Usually, an "immunological response" includes but is not limited to one or more of the following effects: the production or activation of antibodies, B cells, helper T cells, suppressor T cells, and/or cytotoxic T cells and/or yd T cells, directed specifically to an antigen or antigens included in the composition or vaccine of interest. Preferably, the host will display either a therapeutic or protective immunological response such that resistance to new infection will be enhanced and/or the clinical severity of the disease reduced. Such protection will be demonstrated by either a reduction or lack of symptoms normally displayed by an infected host, a quicker recovery time and/or a lowered viral titer in the infected host. Thus, the present invention also relates to method of producing and/or recovering recombinant PCV2 ORF2 protein, preferably in amounts described above, by i) permitting infection of a

number of susceptible cells (see above) in culture with a recombinant viral vector with a MOI as defined above, ii) expressing PCV ORF2 protein by the recombinant viral vector, iii) recovering the PCV2 ORF2 in the supernate of cells obtained between days 5 and 8 after infection and/or cell viability decreases to less then 10%, iv) separating cell debris from the expressed PCV2 ORF2 via a separation step, and v) inactivating the recombinant viral vector.

Preferably, this inactivation is done either just before or just after the filtration step, with after the filtration step being the preferred time for inactivation. Any conventional inactivation method can be used for purposes of the present invention. Thus, inactivation can be performed by chemical and/or physical treatments. In preferred forms, the volume of harvest fluids is determined and the temperature is brought to between about 32-42° C., more preferably between about 34-40° C., and most preferably between about 35-39° C. Preferred inactivation methods include the addition of cyclized binary ethylenimine (BEI), preferably in a concentration of about 1 to about 20 mM, more preferably of about 2 to about 10 mM, still more preferably of about 2 to about 8 mM, still more preferably of about 3 to about 7 mM, and most preferably of about 5 mM. For example the inactivation includes the addition of a solution of 2-bromoethyleneamine hydrobromide, preferably of about 0.4M, which has been cyclized to 0.2M binary ethylenimine (BEI) in 0.3N NaOH, to the fluids to give a final concentration of about 5 mM BEI. Preferably, the fluids are then stirred continuously for 72-96 hours and the inactivated harvest fluids can be stored frozen at −40° C. or below or between about 1-7° C. After inactivation is completed, a sodium thiosulfate solution, preferably at 1.0M is added to neutralize any residual BEI. Preferably, the sodium thiosulfate is added in equivalent amount as compared to the BEI added prior to for inactivation. For example, in the event BEI is added to a final concentration of 5 mM, a 1.0M sodium thiosulfate solution is added to give a final minimum concentration of 5 mM to neutralize any residual BEI.

Thus, one further aspect of the present invention relates to a method of producing recombinant PCV2 ORF2 protein, preferably in amounts described above, by i) permitting infection of a number of susceptible cells (see above) in culture with a recombinant viral vector with a MOI as defined above, ii) expressing PCV ORF2 protein by the recombinant viral vector, iii) recovering the PCV2 ORF2 in the supernate of cells obtained between days 5 and 8 after infection and/or cell viability decreases to less then 10%, iv) separating cell debris from the expressed PCV2 ORF2 via a separation step, and v) inactivating the recombinant viral vector. Preferably, the recombinant viral vector is a baculovirus containing ORF2 DNA coding sequences and the cells are SF+ cells. Preferred separation steps are those described above, most preferred is the filtration step. Preferred inactivation steps are those described above. Preferably, inactivation is performed between about 35-39° C. and in the presence of 2 to 8 mM BEI, and still more preferably in the presence of about 5 mM BEI. It has been surprisingly found, that higher concentrations of BEI negatively affect the PCV2 ORF2 protein.

According to one further aspect of the present invention, the method described above also includes a neutralization step after step v). This step vi) comprises adding of an equivalent amount of an agent that neutralizes the inactivation agent within the solution. Preferably, if the inactivation agent is BEI, addition of sodium thiosulfate to an equivalent amount is preferred. Thus, according to a further aspect, step vi) comprises adding a sodium thiosulfate solution to a final concentration of about 1 to about 20 mM, preferably of about 2 to about 10 mM, still more preferably of about 2 to about 8 mM, still more preferably of about 3 to about 7 mM most preferably of about 5 mM, when the inactivation agent is BEI.

In preferred forms and especially in forms that will use the recombinant PCV2 ORF2 protein in an immunogenic composition such as a vaccine, each lot of harvested ORF2 will be tested for inactivation by passage in the anchorage dependent, baculovirus susceptible Sf+ cells. In a preferred form of this testing, 150 cm^2 of appropriate cell culture monolayer is inoculated with 1.0 mL of inactivated PCV2 fluids and maintained at 25-29° C. for 14 days with at least two passages. At the end of the maintenance period, the cell monolayers are examined for cytopathogenic effect (CPE) typical of PCV2 ORF2 baculovirus. Preferably, positive virus controls are also used. Such controls can consist of one culture of Sf+ cells inoculated with a non-inactivated reference PCV2 ORF2 baculovirus and one flask of Sf+ cells that remain uninoculated. After incubation and passage, the absence of virus-infected cells in the BEI treated viral fluids would constitute a satisfactory inactivation test. The control cells inoculated with the reference virus should exhibit CPE typical of PCV2 ORF2 baculovirus and the uninoculated flask should not exhibit any evidence of PCV2 ORF2 baculovirus CPE. Alternatively, at the end of the maintenance period, the supernatant samples could be collected and inoculated onto a Sf+96 well plate, which has been loaded with Sf+ cells, and then maintained at 25-29° C. for 5-6 days. The plate is then fixed and stained with anti-PCV2 ORF2 antibody conjugated to FITC. The absence of CPE and ORF2 expression, as detected by IFA micoscopy, in the BEI treated viral fluids constitutes a satisfactory inactivation test. The control cells inoculated with the reference virus should exhibit CPE and IFA activity and the uninoculated flask should not exhibit any evidence of PCV2 ORF2 baculovirus CPE and contain no IFA activity.

Thus a further aspect of the present invention relates to an inactivation test for determining the effectiveness of the inactivation of the recombination viral vector, comprising the steps: i) contacting at least a portion of the culture fluid containing the recombinant viral vector with an inactivating agent, preferably as described above, ii) adding a neutralization agent to neutralize the inactivation agent, preferably as described above, and iii) determining the residual infectivity by the assays as described above.

A further aspect of the invention relates to a method for constructing a recombinant viral vector containing PCV2 ORF2 DNA and expressing PCV2 ORF2 protein in high amounts, when infected into susceptible cells. It has been surprisingly found that the recombinant viral vector as provided herewith expresses high amounts, as defined above, of PCV2 ORF2 after infecting susceptible cells. Therefore, the present invention also relates to an improved method for producing and/or recovering of PCV2 ORF2 protein, preferably comprising the steps of: constructing a recombinant viral vector containing PCV2 ORF2 DNA and expressing PCV2 ORF2 protein. Preferably, the viral vector is a recombinant baculorvirus. Details of the method for constructing recombinant viral vectors containing PCV2 ORF2 DNA and expressing PCV2 ORF2 protein, as provided herewith, are described to the following: In preferred forms the recombinant viral vector containing PCV2 ORF 2 DNA and expressing PCV2 ORF2 protein used to infect the cells is generated by transfecting a transfer vector that has had an ORF2 gene cloned therein into a viral vector. Preferably, only the portion of the transfer vector, that contains the ORF2 DNA is transfected into the viral vector. The term "transfected into a viral vector" means, and is used as a synonym for "introducing" or "cloning" a heterologous DNA into a viral vector, such as for

example into a baculovirus vector. The viral vector is preferably but not necessarily a baculovirus.

Thus, according to a further aspect of the present invention, the recombinant viral vector is generated by recombination between a transfer vector containing the heterologous PCV2 ORF2 DNA and a viral vector, preferably a baculorvirus, even more preferably a linearized replication-deficient baculovirus (such as Baculo Gold DNA). A "transfer vector" means a DNA molecule, that includes at least one origin of replication, the heterologous gene, in the present case PCV2 ORF2, and DNA sequences which allow the cloning of said heterologous gene into the viral vector. Preferably the sequences which allow cloning of the heterologous gene into the viral vector are flanking the heterologous gene. Even more preferably, those flanking sequences are at least homologous in parts with sequences of the viral vector. The sequence homology then allows recombination of both molecules, the viral vector, and the transfer vector to generate a recombinant viral vector containing the heterologous gene. One preferred transfer vector is the pVL1392 vector (BD Biosciences Pharmingen), which is designed for co-transfection with the BaculoGold DNA into the preferred Sf+ cell line. Preferably, said transfer vector comprises a PCV2 ORF2 DNA. The construct co-transfected is approximately 10,387 base pairs in length.

In more preferred forms, the methods of the present invention will begin with the isolation of PCV2 ORF2 DNA. Generally, this can be from a known or unknown strain as the ORF2 DNA appears to be highly conserved with at least about 95% sequence identity between different isolates. Any PCV2 ORF2 gene known in the art can be used for purposes of the present invention as each would be expressed into the supernate. The PCV ORF2 DNA is preferably amplified using PCR methods, even more preferably together with the introduction of a 5' flanking Kozak's consensus sequence (CCGCCAUG) (SEQ ID NO 1) and/or a 3' flanking EcoR1 site (GAATTC) (SEQ ID NO 2). Such introduction of a 5'Kozak's consensus preferably removes the naturally occurring start codon AUG of PCV2 ORF2. The 3' EcoR1 site is preferably introduced downstream of the stop codon of the PCV2 ORF2. More preferably it is introduced downstream of a poly A transcription termination sequence, that itself is located downstream of the PCV2 ORF2 stop codon. It has been found, that the use of a Kozak's consensus sequence, in particular as described above, increases the expression level of the subsequent PCV2 ORF2 protein. The amplified PCV2 ORF2 DNA, with these additional sequences, is cloned into a vector. A preferred vector for this initial cloning step is the pGEM-T-Easy Vector (Promega, Madison, Wis.). The PCV2 ORF2 DNA including some pGEM vector sequences (SEQ ID NO: 7) is preferably excised from the vector at the Not1 restriction site. The resulting DNA is then cloned into the transfer vector.

Thus, in one aspect of the present invention, a method for constructing a recombinant viral vector containing PCV2 ORF2 DNA is provided. This method comprises the steps: i) cloning a recombinant PCV2 ORF2 into a transfer vector; and ii) transfecting the portion of the transfer vector containing the recombinant PCV2 ORF2 into a viral vector, to generate the recombinant viral vector. Preferably, the transfer vector is that described above or is constructed as described above or as exemplarily shown in FIG. **1**. Thus according to a further aspect, the transfer vector, used for the construction of the recombinant viral vector as described herein, contains the sequence of SEQ ID NO: 7.

According to a further aspect, this method further comprises prior to step i) the following step: amplifying the PCV2 ORF2 DNA in vitro, wherein the flanking sequences of the PCV2 ORF2 DNA are modified as described above. In vitro methods for amplifying the PCV2 ORF2 DNA and modifying the flanking sequences, cloning in vitro amplified PCV2 ORF2 DNA into a transfer vector and suitable transfer vectors are described above, exemplarily shown in FIG. **1**, or known to a person skilled in the art. Thus according to a further aspect, the present invention relates to a method for constructing a recombinant viral vector containing PCV2 ORF2 DNA and expressing PCV2 ORF2 protein comprises the steps of: i) amplifying PCV2 ORF2 DNA in vitro, wherein the flanking sequences of said PCV2 ORF2 DNA are modified, ii) cloning the amplified PCV2 ORF2 DNA into a transfer vector; and iii) transfecting the transfer vector or a portion thereof containing the recombinant PCV2 ORF2 DNA into a viral vector to generate the recombinant viral vector. Preferably, the modification of the flanking sequences of the PCV2 ORF2 DNA is performed as described above, e.g. by introducing a 5' Kozak's sequence and/or an EcoR 1 site, preferably as described above.

According to a further aspect, a method of producing and/or recovering recombinant protein expressed by open reading frame 2 of PCV2 is provided. The method generally comprises the steps of: i) cloning a recombinant PCV2 ORF2 into a transfer vector; ii) transfecting the portion of the transfer vector containing the recombinant PCV2 ORF2 into a virus; iii) infecting cells in media with the transfected virus; iv) causing the transfected virus to express the recombinant protein from PCV2 ORF2; v) separating cells from the supernate; and vi) recovering the expressed PCV2 ORF2 protein from the supernate.

Methods of how to clone a recombinant PCV2 ORF2 DNA into a transfer vector are described above. Preferably, the transfer vector contains the sequence of SEQ ID NO:3, SEQ ID NO:4, or SEQ ID NO:7. However, the transfer vector can contain any PCV2 ORF2 DNA, unmodified or modified, as long as the PCV2 ORF2 DNA, when transfected into a recombinant viral vector, is expressed in cell culture. Preferably, the recombinant viral vector comprises the sequence of SEQ ID NO:8. Moreover, methods of how to infect cells, preferably how to infect insect cells with a defined number of recombinant baculovirus containing PCV2 ORF2 DNA and expressing PCV2 ORF2 protein, are described above in detail. Moreover, steps of separating cells from the supernate as well as steps for recovering the expressed PCV2 ORF2 protein are also described above in detail. Any of these specific process steps, as described herein, are part of the method of producing and/or recovering recombinant protein expressed by open reading frame 2 of PCV2 as described above. Preferably, the cells are SF+ cells. Still more preferably, cell cultures have a cell count between about $0.3–2.0\times10^6$ cells/mL, more preferably from about $0.35–1.9\times10^6$ cells/mL, still more preferably from about $0.4–1.8\times10^6$ cells/mL, even more preferably from about $0.45–1.7\times10^6$ cells/mL, and most preferably from about $0.5–1.5\times10^6$ cells/mL. Preferably, the recombinant viral vector containing the PCV2 ORF2 DNA has a preferred multiplicity of infection (MOI) of between about 0.03-1.5, more preferably from about 0.05-1.3, still more preferably from about 0.09-1.1, still more preferably from about 0.1-1.0, and most preferably to about 0.5, when used for the infection of the susceptible cells. Preferably, recovering of the PCV2 ORF2 protein in the supernate of cells obtained between days 5 and 8 after infection and/or cell viability decreases to less then 10%. Preferably, for producing PCV2 ORF2 protein, cells are cultivated at 25 to 29° C. Preferably, the separation step is a centrifugation or a filtration step.

Optionally, this method can include the step of amplifying the PCV2 ORF2 DNA from a strain of PCV2 prior to cloning the PCV2 ORF2 DNA into the transfer vector. In preferred

forms, a 5' Kozak's sequence, a 3' EcoR1 site, and combinations thereof can also be added to the amplified sequence, preferably prior to or during amplification. A preferred 5' Kozak's sequence comprises SEQ ID NO: 1. A preferred 3' EcoR1 site comprises SEQ ID NO: 2. Preferred PCV2 ORF2 DNA comprises the nucleotide sequence Genbank Accession No. AF086834 (SEQ ID NO: 3) and SEQ ID NO: 4. Preferred recombinant PCV2 ORF2 protein comprises the amino acid sequence of SEQ ID NO: 5, which is the protein encoded by SEQ ID NO: 3 (Genbank Accession No. AF086834) and SEQ ID No: 6, which is the protein encoded by SEQ ID NO: 4. A preferred media comprises serum-free insect cell media, still more preferably Excell 420 media. When the optional amplification step is performed, it is preferable to first clone the amplified open reading frame 2 into a first vector, excise the open reading frame 2 from the first vector, and use the excised open reading frame for cloning into the transfer vector. A preferred cell line for cotransfection is the SF+ cell line. A preferred virus for cotransfection is baculovirus. In preferred forms of this method, the transfected portion of the transfer vector comprises SEQ ID NO: 8. Finally, for this method, it is preferred to recover the PCV2 open reading frame 2 (ORF2) protein in the cell culture supernate at least 5 days after infecting the cells with the virus.

Thus, a further aspect of the invention relates to a method for producing and/or recovering the PCV2 open reading frame 2, comprises the steps: i) amplifying the PCV2 ORF2 DNA in vitro, preferably by adding a 5' Kozak's sequence and/or by adding a 3' EcoR1 restriction site, ii) cloning the amplified PCV2 ORF2 into a transfer vector; iii) transfecting the portion of the transfer vector containing the recombinant PCV2 ORF2 into a virus; iv) infecting cells in media with the transfected virus; v) causing the transfected virus to express the recombinant protein from PCV2 ORF2; vi) separating cells from the supernate; and vii) recovering the expressed PCV2 ORF2 protein from the supernate.

A further aspect of the present invention relates to a method for preparing a composition comprising PCV2 ORF2 protein, and inactivated viral vector. This method comprises the steps: i) cloning the amplified PCV2 ORF2 into a transfer vector; ii) transfecting the portion of the transfer vector containing the recombinant PCV2 ORF2 into a virus; iii) infecting cells in media with the transfected viral vector; iv) causing the transfected viral vector to express the recombinant protein from PCV2 ORF2; v) separating cells from the supernate; vi) recovering the expressed PCV2 ORF2 protein from the supernate; and vii) inactivating the recombinant viral vector. Preferably, the recombinant viral vector is a baculovirus containing ORF2 DNA coding sequences and the cells are SF+ cells. Preferred separation steps are those described above, most preferred is the filtration step. Preferred inactivation steps are those described above. Preferably, inactivation is performed between about 35-39° C. and in the presence of 2 to 8 mM BEI, still more preferably in the presence of about 5 mM BEI. It has been surprisingly found, that higher concentrations of BEI negatively affect the PCV2 ORF2 protein, and lower concentrations are not effective to inactivate the viral vector within 24 to 72 hours of inactivation. Preferably, inactivation is performed for at least 24 hours, even more preferably for 24 to 72 hours.

According to a further aspect, the method for preparing a composition comprising PCV2 ORF2 protein, and inactivated viral vector, as described above, also includes a neutralization step after step vii). This step viii) comprises adding an equivalent amount of an agent that neutralizes the inactivation agent within the solution. Preferably, if the inactivation agent is BEI, the addition of sodium thiosulfate to an equivalent amount is preferred. Thus, according to a further aspect, step viii) comprises adding a sodium thiosulfate solution to a final concentration of about 1 to about 20 mM, preferably of about 2 to about 10 mM, still more preferably of about 2 to about 8 mM, still more preferably of about 3 to about 7 mM, most preferably of about 5 mM, when the inactivation agent is BEI.

According to a further aspect, the method for preparing a composition comprising PCV2 ORF2 protein, and inactivated viral vector, as described above, comprises prior to step i) the following step: amplifying the PCV2 ORF2 DNA in vitro, wherein the flanking sequences of the PCV2 ORF2 DNA are modified as described above. In vitro methods for amplifying the PCV2 ORF2 DNA and modifying the flanking sequences, cloning in vitro amplified PCV2 ORF2 DNA into a transfer vector and suitable transfer vectors are described above, exemplarily shown in FIG. **1**, or known to a person skilled in the art. Thus according to a further aspect, this method comprises the steps: i) amplifying PCV2 ORF2 DNA in vitro, wherein the flanking sequences of said PCV2 ORF2 DNA are modified, ii) cloning the amplified PCV2 ORF2 DNA into a transfer vector; and iii) transfecting the transfer vector or a portion thereof containing the recombinant PCV2 ORF2 DNA into a viral vector to generate the recombinant viral vector, iv) infecting cells in media with the transfected virus; v) causing the transfected virus to express the recombinant protein from PCV2 ORF2; vi) separating cells from the supernate; vii) recovering the expressed PCV2 ORF2 protein from the supernate; viii) inactivating the recombinant viral vector, preferably, in the presence of about 1 to about 20 mM BEI, most preferably in the presence of about 5 mM BEI; and ix) adding an equivalent amount of an agent that neutralizes the inactivation agent within the solution, preferably, adding of a sodium thiosulfate solution to a final concentration of about 1 to about 20 mM, preferably of about 5 mM, when the inactivation agent is BEI.

In another aspect of the present invention, a method for preparing a composition, preferably an antigenic composition, such as for example a vaccine, for invoking an immune response against PCV2 is provided. Generally, this method includes the steps of transfecting a construct into a virus, wherein the construct comprises i) recombinant DNA from ORF2 of PCV2, ii) infecting cells in growth media with the transfected virus, iii) causing the virus to express the recombinant protein from PCV2 ORF2, iv) recovering the expressed ORF2 protein from the supernate, v) and preparing the composition by combining the recovered protein with a suitable adjuvant and/or other pharmaceutically acceptable carrier.

"Adjuvants" as used herein, can include aluminum hydroxide and aluminum phosphate, saponins e.g., Quil A, QS-21 (Cambridge Biotech Inc., Cambridge Mass.), GPI-0100 (Galenica Pharmaceuticals, Inc., Birmingham, Ala.), water-in-oil emulsion, oil-in-water emulsion, water-in-oil-in-water emulsion. The emulsion can be based in particular on light liquid paraffin oil (European Pharmacopea type); isoprenoid oil such as squalane or squalene oil resulting from theoligomerization of alkenes, in particular of isobutene or decene; esters of acids or of alcohols containing a linear alkyl group, more particularly plant oils, ethyl oleate, propylene glycol di-(caprylate/caprate), glyceryl tri-(caprylate/caprate) or propylene glycol dioleate; esters of branched fatty acids or alcohols, in particular isostearic acid esters. The oil is used in combination with emulsifiers to form the emulsion. The emulsifiers are preferably nonionic surfactants, in particular esters of sorbitan, of mannide (e.g. anhydromannitol oleate), of glycol, of polyglycerol, of propylene glycol and of oleic, isostearic,

ricinoleic or hydroxystearic acid, which are optionally ethoxylated, and polyoxypropylene-polyoxyethylene copolymer blocks, in particular the Pluronic products, especially L121. See Hunter et al., The Theory and Practical Application of Adjuvants (Ed. Stewart-Tull, D. E. S.). JohnWiley and Sons, NY, pp 51-94 (1995) and Todd et al., Vaccine 15:564-570 (1997).

For example, it is possible to use the SPT emulsion described on page 147 of "Vaccine Design, The Subunit and Adjuvant Approach" edited by M. Powell and M. Newman, Plenum Press, 1995, and the emulsion MF59 described on page 183 of this same book.

A further instance of an adjuvant is a compound chosen from the polymers of acrylic or methacrylic acid and the copolymers of maleic anhydride and alkenyl derivative. Advantageous adjuvant compounds are the polymers of acrylic or methacrylic acid which are cross-linked, especially with polyalkenyl ethers of sugars or polyalcohols. These compounds are known by the term carbomer (Phameuropa Vol. 8, No. 2, June 1996). Persons skilled in the art can also refer to U.S. Pat. No. 2,909,462 which describes such acrylic polymers cross-linked with a polyhydroxylated compound having at least 3 hydroxyl groups, preferably not more than 8, the hydrogen atoms of at least three hydroxyls being replaced by unsaturated aliphatic radicals having at least 2 carbon atoms. The preferred radicals are those containing from 2 to 4 carbon atoms, e.g. vinyls, allyls and other ethylenically unsaturated groups. The unsaturated radicals may themselves contain other substituents, such as methyl. The products sold under the name Carbopol; (BF Goodrich, Ohio, USA) are particularly appropriate. They are cross-linked with an allyl sucrose or with allyl pentaerythritol. Among then, there may be mentioned Carbopol 974P, 934P and 971P. Most preferred is the use of Cabopol 971P. Among the copolymers of maleic anhydride and alkenyl derivative, the copolymers EMA (Monsanto) which are copolymers of maleic anhydride and ethylene. The dissolution of these polymers in water leads to an acid solution that will be neutralized, preferably to physiological pH, in order to give the adjuvant solution into which the immunogenic, immunological or vaccine composition itself will be incorporated.

Further suitable adjuvants include, but are not limited to, the RIBI adjuvant system (Ribi Inc.), Block co-polymer (CytRx, Atlanta Ga.), SAF-M (Chiron, Emeryville Calif.), monophosphoryl lipid A, Avridine lipid-amine adjuvant, heat-labile enterotoxin from *E. coli* (recombinant or otherwise), cholera toxin, IMS 1314 or muramyl dipeptide among many others.

Preferably, the adjuvant is added in an amount of about 100 μg to about 10 mg per dose. Even more preferably, the adjuvant is added in an amount of about 100 μg to about 10 mg per dose. Even more preferably, the adjuvant is added in an amount of about 500 μg to about 5 mg per dose. Even more preferably, the adjuvant is added in an amount of about 750 μg to about 2.5 mg per dose. Most preferably, the adjuvant is added in an amount of about 1 mg per dose.

Thus, according to a further aspect, the method for preparing an antigenic composition, such as for example a vaccine, for invoking an immune response against PCV2 comprises i) preparing and recovering PCV2 ORF2 protein, and ii) admixing this with a suitable adjuvant. Preferably, the adjuvant is Carbopol 971P. Even more preferably, Carbopol 971P is added in an amount of about 500 μg to about 5 mg per dose, even more preferably in an amount of about 750 μg to about 2.5 mg per dose and most preferably in an amount of about 1 mg per dose. Preferably, the process step i) includes the process steps as described for the preparation and recovery of PCV2 ORF2. For example, in preferred forms of this method, the construct comprising PCV2 ORF2 DNA is obtained in a transfer vector. Suitable transfer vectors and methods of preparing them are described above. Optionally, the method may include the step of amplifying the ORF2 from a strain of PCV2 through PCR prior to cloning the ORF2 into the transfer vector. Preferred open reading frame sequences, Kozak's sequences, 3' EcoR1 site sequences, recombinant protein sequences, transfected construct sequences, media, cells, and viruses are as described in the previous methods. Another optional step for this method includes cloning the amplified PCV2 ORF2 DNA into a first vector, excising the ORF2 DNA from this first vector, and using this excised PCV2 ORF2 DNA for cloning into the transfer vector. As with the other methods, it is preferred to wait for at least 5 days after infection of the cells by the transfected baculovirus prior to recovery of recombinant ORF2 protein from the supernate. Preferably, the recovery step of this method also includes the step of separating the media from the cells and cell debris. This can be done in a variety of ways but for ease and convenience, it is preferred to filter the cells, cell debris, and growth media through a filter having pores ranging in size from about 0.45 μM to about 1.0 μM. Finally, for this method, it is preferred to include a virus inactivation step prior to combining the recovered recombinant PCV2 ORF2 protein in a composition. This can be done in a variety of ways, but it is preferred in the practice of the present invention to use BEI.

Thus according to a further aspect, this method comprises the steps: i) amplifying PCV2 ORF2 DNA in vitro, wherein the flanking sequences of said PCV2 ORF2 DNA are modified, ii) cloning the amplified PCV2 ORF2 DNA into a transfer vector; and iii) transfecting the transfer vector or a portion thereof containing the recombinant PCV2 ORF2 DNA into a viral vector to generate the recombinant viral vector, iv) infecting cells in media with the transfected virus; v) causing the transfected virus to express the recombinant protein from PCV2 ORF2; vi) separating cells from the supernate; vii) recovering the expressed PCV2 ORF2 protein from the supernate; viii) inactivating the recombinant viral vector, preferably, in the presence of about 1 to about 20 mM BEI, most preferably in the presence of about 5 mM BEI; ix) adding of an equivalent amount of an agent that neutralizes the inactivation agent within the solution, preferably, adding of a sodium thiosulfate solution to a final concentration of about 1 to about 20 mM, preferably of about 5 mM, when the inactivation agent is BEI, and x) adding a suitable amount of an adjuvant, preferably adding Carbopol, more preferably Carbopol 971P, even more preferably in amounts as described above (e.g. of about 500 μg to about 5 mg per dose, even more preferably in an amount of about 750 μg to about 2.5 mg per dose and most preferably in an amount of about 1 mg per dose).

Additionally, the composition can include one or more pharmaceutical-acceptable carriers. As used herein, "a pharmaceutical-acceptable carrier" includes any and all solvents, dispersion media, coatings, stabilizing agents, diluents, preservatives, antibacterial and antifungal agents, isotonic agents, adsorption delaying agents, and the like. Most preferably, the composition provided herewith, contains PCV2 ORF2 protein recovered from the supernate of in vitro cultured cells, wherein said cells were infected with a recombinant viral vector containing PCV2 ORF2 DNA and expressing PCV2 ORF2 protein, and wherein said cell culture was treated with about 2 to about 8 mM BEI, preferably with about 5 mM BEI to inactivate the viral vector, and an equivalent concentration of a neutralization agent, preferably sodium thiosulfate solution, to a final concentration of about

2 to about 8 mM, preferably of about 5 mM, Carbopol, more preferably Carbopol 971P, preferably in amounts of about 500 μg to about 5 mg per dose, even more preferably in an amount of about 750 μg to about 2.5 mg per dose and most preferably in an amount of about 1 mg per dose, and physiological saline, preferably in an amount of about 50 to about 90% (v/v), more preferably to about 60 to 80% (v/v), still more preferably of about 70% (v/v).

Thus, a further aspect relates to a method for preparing an antigenic composition, such as for example a vaccine, for invoking an immune response against PCV2 comprising the steps: i) amplifying PCV2 ORF2 DNA in vitro, wherein the flanking sequences of said PCV2 ORF2 DNA are modified, ii) cloning the amplified PCV2 ORF2 DNA into a transfer vector; and iii) transfecting the transfer vector or a portion thereof containing the recombinant PCV2 ORF2 DNA into a viral vector to generate the recombinant viral vector, iv) infecting cells in media with the transfected virus; v) causing the transfected virus to express the recombinant protein from PCV2 ORF2; vi) separating cells from the supernate; vii) recovering the expressed PCV2 ORF2 protein from the supernate; viii) inactivating the recombinant viral vector, preferably, in the presence of about 2 to about 20 mM BEI, most preferably in the presence of about 5 mM BEI; ix) adding an equivalent amount of an agent that neutralize the inactivation agent within the solution, preferably, adding a sodium thiosulfate solution to a final concentration of about 0.5 to about 20 mM, preferably of about mM, when the inactivation agent is BEI, x) adding a suitable amount of an adjuvant, preferably adding Carbopol, more preferably Carbopol 971P, still more preferably in amounts as described above (e.g. of about 500 μg to about 5 mg per dose, even more preferably in an amount of about 750 μg to about 2.5 mg per dose and most preferably in an amount of about 1 mg per dose); and xi) adding physiological saline, preferably in an amount of about 50 to about 90% (v/v), more preferably to about 60 to 80% (v/v), still more preferably of about 70% (v/v). Optionally, this method can also include the addition of a protectant. A protectant as used herein, refers to an anti-microbiological active agent, such as for example Gentamycin, Merthiolate, and the like. In particular adding a protectant is most preferred for the preparation of a multi-dose composition. Those anti-microbiological active agents are added in concentrations effective to prevent the composition of interest from any microbiological contamination or for inhibition of any microbiological growth within the composition of interest.

Moreover, this method can also comprise the addition of any stabilizing agent, such as for example saccharides, trehalose, mannitol, saccharose and the like, to increase and/or maintain product shelf-life. However, it has been surprisingly found, that the resulting formulation is immunologically effective over a period of at least 24 months, without adding any further stabilizing agent.

A further aspect of the present invention relates to the products resulting from the methods as described above. In particular, the present invention relates to a composition of matter comprising recombinantly expressed PCV2 ORF2 protein. Moreover, the present invention also relates to a composition of matter that comprises recombinantly expressed PCV2 ORF2 protein, recovered from the supernate of an insect cell culture. Moreover, the present invention also relates to a composition of matter comprising recombinantly expressed PCV2 ORF2 protein, recovered from the supernate of an insect cell culture. Preferably, this composition of matter also comprises an agent suitable for the inactivation of viral vectors. Preferably, said inactivation agent is BEI. Moreover, the present invention also relates to a composition of matter that comprises recombinantly expressed PCV2 ORF2 protein, recovered from the supernate of an insect cell culture, and comprises an agent, suitable for the inactivation of viral vectors, preferably BEI and a neutralization agent for neutralization of the inactivation agent. Preferably, that neutralization agent is sodium thiosulfate, when BEI is used as an inactivation agent.

In yet another aspect of the present invention, an immunogenic composition that induces an immune response and, more preferably, confers protective immunity against the clinical signs of PCV2 infection, is provided. The composition generally comprises the polypeptide, or a fragment thereof, expressed by Open Reading Frame 2 (ORF2) of PCV2, as the antigenic component of the composition.

PCV2 ORF2 DNA and protein, as used herein for the preparation of the compositions and also as used within the processes provided herein is a highly conserved domain within PCV2 isolates and thereby, any PCV2 ORF2 would be effective as the source of the PCV ORF2 DNA and/or polypeptide as used herein. A preferred PCV2 ORF2 protein is that of SEQ ID NO. 11. A preferred PCV ORF2 polypeptide is provided herein as SEQ ID NO. 5, but it is understood by those of skill in the art that this sequence could vary by as much as 6-10% in sequence homology and still retain the antigenic characteristics that render it useful in immunogenic compositions. The antigenic characteristics of an immunological composition can be, for example, estimated by the challenge experiment as provided by Example 4. Moreover, the antigenic characteristic of an modified antigen is still retained, when the modified antigen confers at least 70%, preferably 80%, more preferably 90% of the protective immunity as compared to the PCV2 ORF 2 protein, encoded by the polynucleotide sequence of SEQ ID NO:3 or SEQ ID NO:4. An "immunogenic composition" as used herein, means a PCV2 ORF2 protein which elicits an "immunological response" in the host of a cellular and/or antibody-mediated immune response to PCV2 ORF2 protein. Preferably, this immunogenic composition is capable of conferring protective immunity against PCV2 infection and the clinical signs associated therewith. In some forms, immunogenic portions of PCV2 ORF2 protein are used as the antigenic component in the composition. The term "immunogenic portion" as used herein refers to truncated and/or substituted forms, or fragments of PCV2 ORF2 protein and/or polynucleotide, respectively. Preferably, such truncated and/or substituted forms, or fragments will comprise at least 6 contiguous amino acids from the full-length ORF2 polypeptide. More preferably, the truncated or substituted forms, or fragments will have at least 10, more preferably at least 15, and still more preferably at least 19 contiguous amino acids from the full-length ORF2 polypeptide. Two preferred sequences in this respect are provided herein as SEQ ID NOs. 9 and 10. It is further understood that such sequences may be a part of larger fragments or truncated forms. A further preferred PCV2 ORF2 polypeptide provided herein is encoded by the nucleotide sequences of SEQ ID NO: 3 or SEQ ID NO: 4. But it is understood by those of skill in the art that this sequence could vary by as much as 6-20% in sequence homology and still retain the antigenic characteristics that render it useful in immunogenic compositions. In some forms, a truncated or substituted form, or fragment of ORF2 is used as the antigenic component in the composition. Preferably, such truncated or substituted forms, or fragments will comprise at least 18 contiguous nucleotides from the full-length ORF2 nucleotide sequence, e.g. of SEQ ID NO: 3 or SEQ ID NO: 4. More preferably, the truncated or substituted forms, or fragments will have at least 30, more preferably at least 45, and still more preferably at

least 57 contiguous nucleotides the full-length ORF2 nucleotide sequence, e.g. of SEQ ID NO: 3 or SEQ ID NO: 4.

"Sequence Identity" as it is known in the art refers to a relationship between two or more polypeptide sequences or two or more polynucleotide sequences, namely a reference sequence and a given sequence to be compared with the reference sequence. Sequence identity is determined by comparing the given sequence to the reference sequence after the sequences have been optimally aligned to produce the highest degree of sequence similarity, as determined by the match between strings of such sequences. Upon such alignment, sequence identity is ascertained on a position-by-position basis, e.g., the sequences are "identical" at a particular position if at that position, the nucleotides or amino acid residues are identical. The total number of such position identities is then divided by the total number of nucleotides or residues in the reference sequence to give % sequence identity. Sequence identity can be readily calculated by known methods, including but not limited to, those described in Computational Molecular Biology, Lesk, A. N., ed., Oxford University Press, New York (1988), Biocomputing: Informatics and Genome Projects, Smith, D. W., ed., Academic Press, New York (1993); Computer Analysis of Sequence Data, Part I, Griffin, A. M., and Griffin, H. G., eds., Humana Press, New Jersey (1994); Sequence Analysis in Molecular Biology, von Heinge, G., Academic Press (1987); Sequence Analysis Primer, Gribskov, M. and Devereux, J., eds., M. Stockton Press, New York (1991); and Carillo, H., and Lipman, D., SIAM J. Applied Math., 48: 1073 (1988), the teachings of which are incorporated herein by reference. Preferred methods to determine the sequence identity are designed to give the largest match between the sequences tested. Methods to determine sequence identity are codified in publicly available computer programs which determine sequence identity between given sequences. Examples of such programs include, but are not limited to, the GCG program package (Devereux, J., et al., Nucleic Acids Research, 12(1):387 (1984)), BLASTP, BLASTN and FASTA (Altschul, S. F. et al., J. Molec. Biol., 215:403-410 (1990). The BLASTX program is publicly available from NCBI and other sources (BLAST Manual, Altschul, S. et al., NCVI NLM NIH Bethesda, Md. 20894, Altschul, S. F. et al., J. Molec. Biol., 215:403-410 (1990), the teachings of which are incorporated herein by reference). These programs optimally align sequences using default gap weights in order to produce the highest level of sequence identity between the given and reference sequences. As an illustration, by a polynucleotide having a nucleotide sequence having at least, for example, 85%, preferably 90%, even more preferably 95% "sequence identity" to a reference nucleotide sequence, it is intended that the nucleotide sequence of the given polynucleotide is identical to the reference sequence except that the given polynucleotide sequence may include up to 15, preferably up to 10, even more preferably up to 5 point mutations per each 100 nucleotides of the reference nucleotide sequence. In other words, in a polynucleotide having a nucleotide sequence having at least 85%, preferably 90%, even more preferably 95% identity relative to the reference nucleotide sequence, up to 15%, preferably 10%, even more preferably 5% of the nucleotides in the reference sequence may be deleted or substituted with another nucleotide, or a number of nucleotides up to 15%, preferably 10%, even more preferably 5% of the total nucleotides in the reference sequence may be inserted into the reference sequence. These mutations of the reference sequence may occur at the 5' or 3' terminal positions of the reference nucleotide sequence or anywhere between those terminal positions, interspersed either individually among nucleotides in the reference sequence or in one or more contiguous groups within the reference sequence. Analogously, by a polypeptide having a given amino acid sequence having at least, for example, 85%, preferably 90%, even more preferably 95% sequence identity to a reference amino acid sequence, it is intended that the given amino acid sequence of the polypeptide is identical to the reference sequence except that the given polypeptide sequence may include up to 15, preferably up to 10, even more preferably up to 5 amino acid alterations per each 100 amino acids of the reference amino acid sequence. In other words, to obtain a given polypeptide sequence having at least 85%, preferably 90%, even more preferably 95% sequence identity with a reference amino acid sequence, up to 15%, preferably up to 10%, even more preferably up to 5% of the amino acid residues in the reference sequence may be deleted or substituted with another amino acid, or a number of amino acids up to 15%, preferably up to 10%, even more preferably up to 5% of the total number of amino acid residues in the reference sequence may be inserted into the reference sequence. These alterations of the reference sequence may occur at the amino or the carboxy terminal positions of the reference amino acid sequence or anywhere between those terminal positions, interspersed either individually among residues in the reference sequence or in the one or more contiguous groups within the reference sequence. Preferably, residue positions which are not identical differ by conservative amino acid substitutions. However, conservative substitutions are not included as a match when determining sequence identity.

"Sequence homology", as used herein, refers to a method of determining the relatedness of two sequences. To determine sequence homology, two or more sequences are optimally aligned, and gaps are introduced if necessary. However, in contrast to "sequence identity", conservative amino acid substitutions are counted as a match when determining sequence homology. In other words, to obtain a polypeptide or polynucleotide having 95% sequence homology with a reference sequence, 85%, preferably 90%, even more preferably 95% of the amino acid residues or nucleotides in the reference sequence must match or comprise a conservative substitution with another amino acid or nucleotide, or a number of amino acids or nucleotides up to 15%, preferably up to 10%, even more preferably up to 5% of the total amino acid residues or nucleotides, not including conservative substitutions, in the reference sequence may be inserted into the reference sequence. Preferably the homologous sequence comprises at least a stretch of 50, even more preferably 100, even more preferably 250, even more preferably 500 nucleotides.

A "conservative substitution" refers to the substitution of an amino acid residue or nucleotide with another amino acid residue or nucleotide having similar characteristics or properties including size, hydrophobicity, etc., such that the overall functionality does not change significantly.

Isolated" means altered "by the hand of man" from its natural state, i.e., if it occurs in nature, it has been changed or removed from its original environment, or both. For example, a polynucleotide or polypeptide naturally present in a living organism is not "isolated," but the same polynucleotide or polypeptide separated from the coexisting materials of its natural state is "isolated", as the term is employed herein.

Thus, a further aspect of the present invention relates to an immunogenic composition effective for lessening the severity of clinical symptoms associated with PCV2 infection comprising PCV2 ORF2 protein. Preferably, the PCV2 ORF2 protein is anyone of those, described above. Preferably, said PCV2 ORF2 protein is

i) a polypeptide comprising the sequence of SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 9, SEQ ID NO: 10 or SEQ ID NO: 11;

ii) any polypeptide that is at least 80% homologous to the polypeptide of i),

iii) any immunogenic portion of the polypeptides of i) and/or ii)

iv) the immunogenic portion of iii), comprising at least 10 contiguous amino acids included in the sequences of SEQ ID NO: 5, SEQ ID NO: 6, SEQ ID NO: 9, SEQ ID NO: 10 or SEQ ID NO: 11,

v) a polypeptide that is encoded by a DNA comprising the sequence of SEQ ID NO: 3 or SEQ ID NO: 4.

vi) any polypeptide that is encoded by a polynucleotide that is at least 80% homologous to the polynucleotide of v),

vii) any immunogenic portion of the polypeptides encoded by the polynucleotide of v) and/or vi)

viii) the immunogenic portion of vii), wherein the polynucleotide coding for said immunogenic portion comprises at least 30 contiguous nucleotides included in the sequences of SEQ ID NO: 3, or SEQ ID NO: 4.

Preferably any of those immunogenic portions will have the immunogenic characteristics of PCV2 ORF2 protein that is encoded by the sequence of SEQ ID NO: 3 or SEQ ID NO: 4.

According to a further aspect, PCV2 ORF2 protein is provided in the immunological composition at an antigen inclusion level effective for inducing the desired immune response, namely reducing the incidence of or lessening the severity of clinical signs resulting from PCV2 infection. Preferably, the PCV2 ORF2 protein inclusion level is at least 0.2 μg antigen/ml of the final immunogenic composition (μg/ml), more preferably from about 0.2 to about 400 μg/ml, still more preferably from about 0.3 to about 200 μg/ml, even more preferably from about 0.35 to about 100 μg/ml, still more preferably from about 0.4 to about 50 μg/ml, still more preferably from about 0.45 to about 30 μg/ml, still more preferably from about 0.6 to about 15 μg/ml, even more preferably from about 0.75 to about 8 μg/ml, even more preferably from about 1.0 to about 6 μg/ml, still more preferably from about 1.3 to about 3.0 μg/ml, even more preferably from about 1.4 to about 2.5 μg/ml, even more preferably from about 1.5 to about 2.0 μg/ml, and most preferably about 1.6 μg/ml.

According to a further aspect, the ORF2 antigen inclusion level is at least 0.2 μg PCV2 ORF2 protein, as described above, per dose of the final antigenic composition (μg/dose), more preferably from about 0.2 to about 400 μg/dose, still more preferably from about 0.3 to about 200 μg/dose, even more preferably from about 0.35 to about 100 μg/dose, still more preferably from about 0.4 to about 50 μg/dose, still more preferably from about 0.45 to about 30 μg/dose, still more preferably from about 0.6 to about 15 μg/dose, even more preferably from about 0.75 to about 8 μg/dose, even more preferably from about 1.0 to about 6 μg/dose, still more preferably from about 1.3 to about 3.0 μg/dose, even more preferably from about 1.4 to about 2.5 μg/dose, even more preferably from about 1.5 to about 2.0 μg/dose, and most preferably about 1.6 μg/dose.

The PCV2 ORF2 polypeptide used in an immunogenic composition in accordance with the present invention can be derived in any fashion including isolation and purification of PCV2 ORF2, standard protein synthesis, and recombinant methodology. Preferred methods for obtaining PCV2 ORF2 polypeptide are described herein above and are also provided in U.S. patent application Ser. No. 11/034,797, the teachings and content of which are hereby incorporated by reference. Briefly, susceptible cells are infected with a recombinant viral vector containing PCV2 ORF2 DNA coding sequences, PCV2 ORF2 polypeptide is expressed by the recombinant virus, and the expressed PCV2 ORF2 polypeptide is recovered from the supernate by filtration and inactivated by any conventional method, preferably using binary ethylenimine, which is then neutralized to stop the inactivation process.

Thus, according to a further aspect the immunogenic composition comprises i) any of the PCV2 ORF2 protein described above, preferably in concentrations described above, and ii) at least a portion of the viral vector expressing said PCV2 ORF2 protein, preferably of a recombinant baculovirus. Moreover, according to a further aspect, the immunogenic composition comprises i) any of the PCV2 ORF2 protein described above, preferably in concentrations described above, ii) at least a portion of the viral vector expressing said PCV2 ORF2 protein, preferably of a recombinant baculovirus, and iii) a portion of the cell culture supernate.

According to one specific embodiment of the production and recovery process for PCV2 ORF2 protein, the cell culture supernate is filtered through a membrane having a pore size, preferably between about 0.45 to 1 μm. Thus, a further aspect relates to an immunogenic composition that comprises i) any of the PCV2 ORF2 protein described above, preferably in concentrations described above, ii) at least a portion of the viral vector expressing said PCV2 ORF2 protein, preferably of a recombinant baculovirus, and iii) a portion of the cell culture; wherein about 90% of the components have a size smaller than 1 μm.

According to a further aspect, the present invention relates to an immunogenic composition that comprises i) any of the PCV2 ORF2 protein described above, preferably in concentrations described above, ii) at least a portion of the viral vector expressing said PCV2 ORF2 protein, iii) a portion of the cell culture, iv) and inactivating agent to inactivate the recombinant viral vector preferably BEI, wherein about 90% of the components i) to iii) have a size smaller than 1 μm. Preferably, BEI is present in concentrations effective to inactivate the baculovirus. Effective concentrations are described above.

According to a further aspect, the present invention relates to an immunogenic composition that comprises i) any of the PCV2 ORF2 protein described above, preferably in concentrations described above, ii) at least a portion of the viral vector expressing said PCV2 ORF2 protein, iii) a portion of the cell culture, iv) an inactivating agent to inactivate the recombinant viral vector preferably BEI, and v) an neutralization agent to stop the inactivation mediated by the inactivating agent, wherein about 90% of the components i) to iii) have a size smaller than 1 μm. Preferably, if the inactivating agent is BEI, said composition comprises sodium thiosulfate in equivalent amounts to BEI.

The polypeptide is incorporated into a composition that can be administered to an animal susceptible to PCV2 infection. In preferred forms, the composition may also include additional components known to those of skill in the art (see also Remington's Pharmaceutical Sciences. (1990). 18th ed. Mack Publ., Easton). Additionally, the composition may include one or more veterinary-acceptable carriers. As used herein, "a veterinary-acceptable carrier" includes any and all solvents, dispersion media, coatings, adjuvants, stabilizing agents, diluents, preservatives, antibacterial and antifungal agents, isotonic agents, adsorption delaying agents, and the like.

In a preferred embodiment, the immunogenic composition comprises PCV2 ORF2 protein as provided herewith, preferably in concentrations described above as an antigenic com-

ponent, which is mixed with an adjuvant, preferably Carbopol, and physiological saline.

Those of skill in the art will understand that the composition herein may incorporate known injectable, physiologically acceptable, sterile solutions. For preparing a ready-to-use solution for parenteral injection or infusion, aqueous isotonic solutions, such as e.g. saline or corresponding plasma protein solutions are readily available. In addition, the immunogenic and vaccine compositions of the present invention can include diluents, isotonic agents, stabilizers, or adjuvants. Diluents can include water, saline, dextrose, ethanol, glycerol, and the like. Isotonic agents can include sodium chloride, dextrose, mannitol, sorbitol, and lactose, among others. Stabilizers include albumin and alkali salts of ethylendiamintetracetic acid, among others. Suitable adjuvants, are those described above. Most preferred is the use of Carbopol, in particular the use of Carbopol 971P, preferably in amounts as described above (e.g. of about 500 μg to about 5 mg per dose, even more preferably in an amount of about 750 μg to about 2.5 mg per dose and most preferably in an amount of about 1 mg per dose).

Thus, the present invention also relates to an immunogenic composition that comprises i) any of the PCV2 ORF2 proteins described above, preferably in concentrations described above, ii) at least a portion of the viral vector expressing said PCV2 ORF2 protein, iii) a portion of the cell culture, iv) an inactivating agent to inactivate the recombinant viral vector, preferably BEI, and v) a neutralization agent to stop the inactivation mediated by the inactivating agent, preferably sodium thiosulfate in equivalent amounts to BEI; and vi) a suitable adjuvant, preferably Carbopol 971, in amounts described above; wherein about 90% of the components i) to iii) have a size smaller than 1 μm. According to a further aspect, this immunogenic composition further comprises a pharmaceutical acceptable salt, preferably a phosphate salt in physiologically acceptable concentrations. Preferably, the pH of said immunogenic composition is adjusted to a physiological pH, meaning between about 6.5 and 7.5.

Thus, the present invention also relates to an immunogenic composition comprises per one ml i) at least 1.6 μg of PCV2 ORF2 protein described above, ii) at least a portion of baculovirus expressing said PCV2 ORF2 protein iii) a portion of the cell culture, iv) about 2 to 8 mM BEI, v) sodium thiosulfate in equivalent amounts to BEI; and vi) about 1 mg Carbopol 971, and vii) phosphate salt in a physiologically acceptable concentration; wherein about 90% of the components i) to iii) have a size smaller than 1 μm and the pH of said immunogenic composition is adjusted to about 6.5 to 7.5.

The immunogenic compositions can further include one or more other immunomodulatory agents such as, e.g., interleukins, interferons, or other cytokines. The immunogenic compositions can also include Gentamicin and Merthiolate. While the amounts and concentrations of adjuvants and additives useful in the context of the present invention can readily be determined by the skilled artisan, the present invention contemplates compositions comprising from about 50 μg to about 2000 μg of adjuvant and preferably about 250 μg/ml dose of the vaccine composition. In another preferred embodiment, the present invention contemplates vaccine compositions comprising from about 1 μg/ml to about 60 μg/ml of antibiotics, and more preferably less than about 30 μg/ml of antibiotics.

Thus, the present invention also relates to an immunogenic composition that comprises i) any of the PCV2 ORF2 proteins described above, preferably in concentrations described above, ii) at least a portion of the viral vector expressing said PCV2 ORF2 protein, iii) a portion of the cell culture, iv) an inactivating agent to inactivate the recombinant viral vector preferably BEI, and v) an neutralization agent to stop the inactivation mediated by the inactivating agent, preferably sodium thiosulfate in equivalent amounts to BEI; vi) a suitable adjuvant, preferably Carbopol 971 in amounts described above; vii) a pharmaceutical acceptable concentration of a saline buffer, preferably of a phosphate salt, and viii) an anti-microbiological active agent; wherein about 90% of the components i) to iii) have a size smaller than 1 μm.

It has been surprisingly found, that the immunogenic composition provided herewith comprises was highly stable over a period of 24 months. It has also been found the immunogenic compositions provided herewith, comprising recombinant, baculovirus expressed PCV2 ORF2 protein as provided herewith are very effective in reducing the clinical symptoms associated with PCV2 infections. It has been surprisingly found, that the immunogenic compositions comprising the recombinant baculovirus expressed PCV2 ORF2 protein as provided herewith, are more effective than an immunogenic composition comprising the whole PCV2 virus in an inactivated form, or isolated viral PCV2 ORF2 antigen. In particular, it has been surprisingly found, that the recombinant baculovirus expressed PCV2 ORF2 protein is effective is in very low concentrations, which means in concentrations up to 0.25 μg/dose. This unexpected high immunogenic potential of the PCV2 ORF2 protein could be further increased by the addition of Carbopol.

A further aspect relates to a container comprising at least one dose of the immunogenic composition of PCV2 ORF2 protein as provided herewith, wherein one dose comprises at least 2 μg PCV2 ORF2 protein, preferably 2 to 16 μg PCV2 ORF2 protein. Said container can comprise from 1 to 250 doses of the immunogenic composition, preferably it contains 1, 10, 25, 50, 100, 150, 200, or 250 doses of the immunogenic composition of PCV2 ORF2 protein. Preferably, each of the containers comprising more than one dose of the immunogenic composition of PCV2 ORF2 protein further comprises an anti-microbiological active agent. Those agents are for example, antibiotics including Gentamicin and Merthiolate and the like. Thus, one aspect of the present invention relates to a container that comprises from 1 to 250 doses of the immunogenic composition of PCV2 ORF2 protein, wherein one dose comprises at least 2 μg PCV2 ORF2 protein, and Gentamicin and/or Merthiolate, preferably from about 1 μg/ml to about 60 μg/ml of antibiotics, and more preferably less than about 30 μg/ml.

A further aspect relates to a kit, comprising any of the containers, described above, and an instruction manual, including the information for the intramuscular application of at least one dose of the immunogenic composition of PCV2 ORF2 protein into piglets to lessen the severity of clinical symptoms associated with PCV2 infection. Moreover, according to a further aspect, said instruction manual comprises the information of a second or further administration(s) of at least one dose of the immunogenic composition of PCV2 ORF2, wherein the second administration or any further administration is at least 14 days beyond the initial or any former administration. Preferably, said instruction manual also includes the information, to administer an immune stimulant. Preferably, said immune stimulant shall be given at least twice. Preferably, at least 3, more preferably at least 5, and even more preferably at least 7 days are between the first and the second or any further administration of the immune stimulant. Preferably, the immune stimulant is given at least 10 days, preferably 15, even more preferably 20, and still even more preferably at least 22 days beyond the initial administration of the immunogenic composition of PCV2 ORF2 pro-

tein. A preferred immune stimulant is for example is keyhole limpet hemocyanin (KLH), preferably emulsified with incomplete Freund's adjuvant (KLH/ICFA). However, it is herewith understood, that any other immune stimulant known to a person skilled in the art can also be used "Immune stimulant" as used herein, means any agent or composition that can trigger a general immune response, preferably without initiating or increasing a specific immune response, for example the immune response against a specific pathogen. It is further instructed to administer the immune stimulant in a suitable dose. Moreover, the kit may also comprise a container, including at least one dose of the immune stimulant, preferably one dose of KLH, or KLH/ICFA.

Moreover, it has also been surprisingly found that the immunogenic potential of the immunogenic compositions comprising recombinant baculovirus expressed PCV2 ORF2 protein, preferably in combination with Carbopol, can be further enhanced by the administration of the IngelVac PRRS MLV vaccine (see Example 5). PCV2 clinical signs and disease manifestations are greatly magnified when PRRS infection is present. However, the immunogenic compositions and vaccination strategies as provided herewith lessened this effect greatly, and more than expected. In other words, an unexpected synergistic effect was observed when animals, preferably pigs, are treated with any of the PCV2 ORF2 immunogenic compositions, as provided herewith, and the Ingelvac PRRS MLV vaccine (Boehringer Ingelheim).

Thus, a further aspect of the present invention relates to the kit as described above, comprising the immunogenic composition of PCV2 ORF2 as provided herewith and the instruction manual, wherein the instruction manual further includes the information to administer the PCV2 ORF2 immunogenic composition together, or around the same time as, with an immunogenic composition that comprises PRRS antigen, preferably adjuvanted PRRS antigen. Preferably, the PRRS antigen is IngelVac® PRRS MLV (Boehringer Ingelheim).

A further aspect of the present invention also relates to a kit comprising i) a container containing at least one dose of an immunogenic composition of PCV2 ORF2 as provided herewith, and ii) a container containing an immunogenic composition comprising PRRS antigen, preferably adjuvanted PRRS antigen. Preferably the PRRS antigen is IngelVac® PRRS MLV (Boehringer Ingelheim). More preferably, the kit further comprises an instruction manual, including the information to administer both pharmaceutical compositions. Preferably, it contains the information that the PCV2 ORF2 containing composition is administered temporally prior to the PRRS containing composition.

A further aspect, relates to the use of any of the compositions provided herewith as a medicament, preferably as a veterinary medicament, even more preferably as a vaccine. Moreover, the present invention also relates to the use of any of the compositions described herein, for the preparation of a medicament for lessening the severity of clinical symptoms associated with PCV2 infection. Preferably, the medicament is for the prevention of a PCV2 infection, even more preferably in piglets.

A further aspect relates to a method for (i) the prevention of an infection, or re-infection with PCV2 or (ii) the reduction or elimination of clinical symptoms caused by PCV2 in a subject, comprising administering any of the immunogenic compositions provided herewith to a subject in need thereof. Preferably, the subject is a pig. Preferably, the immunogenic composition is administered intramuscularly. Preferably, one dose or two doses of the immunogenic composition is/are administered, wherein one dose preferably comprises at least about 2 μg PCV2 ORF2 protein, even more preferably about 2 to about 16 μg, and at least about 0.1 to about 5 mg Carbopol, preferably about 1 mg Carbopol. A further aspect relates to the method of treatment as described above, wherein a second application of the immunogenic composition is administered. Preferably, the second administration is done with the same immunogenic composition, preferably having the same amount of PCV2 ORF2 protein. Preferably the second administration is also given intramuscularly. Preferably, the second administration is done at least 14 days beyond the initial administration, even more preferably at least 4 weeks beyond the initial administration.

According to a further aspect, the method of treatment also comprises the administration of an immune stimulant. Preferably, said immune stimulant is administered at least twice. Preferably, at least 3, more preferably at least 5 days, even more preferably at least 7 days are between the first and the second administration of the immune stimulant. Preferably, the immune stimulant is administered at least 10 days, preferably 15, even more preferably 20, still more preferably at least 22 days beyond the initial administration of the PCV2 ORF2 immunogenic composition. A preferred immune stimulant is for example is keyhole limpet hemocyanin (KLH), still preferably emulsified with incomplete Freund's adjuvant (KLH/ICFA). However, it is herewith understood, that any other immune stimulant known to a person skilled in the art can also be used. It is within the general knowledge of a person skilled in the art to administer the immune stimulant in a suitable dose.

According to a further aspect, the method of treatments described above also comprises the administration of PRRS antigen. Preferably the PRRS antigen is IngelVac® PRRS MLV (Boehringer Ingelheim). Preferably, said PRRS antigen is administered temporally beyond the administration of the immunogenic composition of PCV2 ORF2 protein.

According to a further aspect, the present invention provides a multivalent combination vaccine which includes an immunological agent effective for reducing the incidence of or lessening the severity of PCV2 infection, and at least one immunogenic active component against another disease-causing organism in swine.

In particular the immunological agent effective for reducing the incidence of or lessening the severity of PCV2 infection is a PCV2 antigen. Preferably, said PCV2 antigen is a PCV2 ORF2 protein as provided herewith, or any immunogenic composition as described above, that comprises PCV2 ORF2 protein.

However it is herewith understood, that a PCV2 antigen also refers to any composition of matter that comprises at least one antigen that can induce, stimulate or enhance the immune response against PCV2 infection, when administered to a pig. Preferably, said PCV2 antigen is the whole PCV2 virus, preferably in an inactivated form, a life modified or attenuated PCV2 virus, a chimeric virus that comprises at least an immunogenic amino acid sequence of PCV2, any other polypeptide or component that comprises at least an immunogenic amino acid sequence of PCV2. The terms "immunogenic protein", "immunogenic polypeptide" or "immunogenic amino acid sequence" as used herein refer to any amino acid sequence which elicits an immune response in a host against a pathogen comprising said immunogenic protein, immunogenic polypeptide or immunogenic amino acid sequence. An "immunogenic protein", "immunogenic polypeptide" or "immunogenic amino acid sequence" as used herein, includes the full-length sequence of any proteins, analogs thereof, or immunogenic fragments thereof. By "immunogenic fragment" is meant a fragment of a protein which includes one or more epitopes and thus elicits the

immunological response against the relevant pathogen. Such fragments can be identified using any number of epitope mapping techniques, well known in the art. See, e.g., Epitope Mapping Protocols in Methods in Molecular Biology, Vol. 66 (Glenn E. Morris, Ed., 1996) Humana Press, Totowa, N.J. For example, linear epitopes may be determined by e.g., concurrently synthesizing large numbers of peptides on solid supports, the peptides corresponding to portions of the protein molecule, and reacting the peptides with antibodies while the peptides are still attached to the supports. Such techniques are known in the art and described in, e.g., U.S. Pat. No. 4,708,871; Geysen et al. (1984) Proc. Natl. Acad. Sci. USA 81:3998-4002; Geysen et al. (1986) Molec. Immunol. 23:709-715. Similarly, conformational epitopes are readily identified by determining spatial conformation of amino acids such as by, e.g., x-ray crystallography and 2-dimensional nuclear magnetic resonance. See, e.g., Epitope Mapping Protocols, supra. Synthetic antigens are also included within the definition, for example, polyepitopes, flanking epitopes, and other recombinant or synthetically derived antigens. See, e.g., Bergmann et al. (1993) Eur. J. Immunol. 23:2777-2781; Bergmann et al. (1996), J. Immunol. 157: 3242-3249; Suhrbier, A. (1997), Immunol. and Cell Biol. 75:402-408; Gardner et al., (1998) 12th World AIDS Conference, Geneva, Switzerland, June 28-Jul. 3, 1998.

According to further embodiment, said PCV-2 antigen is Inglevac® CircoFLEX™, (Boehringer Ingelheim Vetmedica Inc, St Joseph, Mo., USA), CircoVac® (Merial SAS, Lyon, France), CircoVent (Intervet Inc., Millsboro, Del., USA), or Suvaxyn PCV-2 One Dose® (Fort Dodge Animal Health, Kansas City, Kans., USA).

An "immunological or immune response" to a composition or vaccine is the development in the host of a cellular and/or antibody-mediated immune response to the composition or vaccine of interest. Usually, an "immune response" includes but is not limited to one or more of the following effects: the production or activation of antibodies, B cells, helper T cells, suppressor T cells, and/or cytotoxic T cells and/or yd T cells, directed specifically to an antigen or antigens included in the composition or vaccine of interest. Preferably, the host will display either a therapeutic or protective immunological response such that resistance to new infection will be enhanced and/or the clinical severity of the disease reduced. Such protection will be demonstrated by either a reduction or lack of the symptoms associated with host infections as described above.

Preferably the other disease-causing organism in swine is selected from the group consisting of: *Actinobacillus pleuropneumonia* (1); Adenovirus (2); Alphavirus such as Eastern equine encephalomyelitis viruses (3); *Bordetella bronchiseptica* (4); *Brachyspira* spp. (5), preferably B. hyodyentheriae (6); B. piosicoli (7), *Brucella suis*, preferably biovars 1, 2, and 3 (8); Classical swine fever virus (9); *Clostridium* spp. (10), preferably Cl. difficile (11), Cl. perfringens types A, B, and C (12), Cl. novyi (13), Cl. septicum (14), Cl. tetani (15); Coronavirus (16), preferably Porcine Respiratory Corona virus (17); *Eperythrozoonosis suis* (18); *Erysipelothrix* rhsiopathiae (19) *Escherichia coli* (20); *Haemophilus* parasuis, preferably subtypes 1, 7 and 14 (21) Hemagglutinating encephalomyelitis virus (22); Japanese Encephalitis Virus (23); *Lawsonia intracellularis* (24) *Leptospira* spp. (25), preferably *Leptospira* australis (26); *Leptospira* canicola (27); *Leptospira* grippotyphosa (28); *Leptospira* icterohaemorrhagicae (29); and *Leptospira* interrogans (30); *Leptospira* pomona (31); *Leptospira* tarassovi (32); *Mycobacterium* spp. (33) preferably *M. avium* (34), *M. intracellulare* (35) and M. bovis (36); *Mycoplasma hyopneumoniae* (M hyo) (37) *Pasteurella multocida* (38); Porcine cytomegalovirus (39); Porcine Parvovirus (40); Porcine Reproductive and Respiratory Syndrome (PRRS) Virus (41) Pseudorabies virus (42); Rotavirus (43); *Salmonella* spp. (44), preferably S. thyhimurium (45) and *S. choleraesuis* (46); *Staph. hyicus* (47); *Staphylococcus* spp. (48) preferably *Streptococcus* spp. (49), preferably Strep. suis (50); Swine herpes virus (51); Swine Influenza Virus (52); Swine pox virus (53); Swine pox virus (54); Vesicular stomatitis virus (55); Virus of vesicular exanthema of swine (56); *Leptospira* Hardjo (57); and/or *Mycoplasma hyosynoviae* (58).

Any reference made in connection with a swine pathogen in the following can be made by naming the pathpgen, for example M. hyo, or by making reference to the number in ( ) behind the pathogen, that is found above. For example reference to M. hyo can be made by M. hyo or by (37).

Thus, the present invention relates to a combination vaccine for the treatment and/or prophylaxis of swine, that includes an immunological agent effective for reducing the incidence of or lessening the severity of PCV2 infection, preferably a PCV2 antigen, and further an immunological active component effective for the treatment and/or prophylaxis of infections caused by any of the swine pathogens (1), (2), (3), (4), (5), (6), (7), (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (18), (19), (20), (21), (22), (23), (24), (25), (26), (27), (28), (29), (30), (31), (32), (33), (34), (35), (36), (37), (38), (39), (40), (41), (42), (43), (44), (45), (46), (47), (48), (49), (50), (51), (52), (53), (54), (55), (56), (57) and/or (58), or is an immunological active component of said swine pathogen(s). [combo 1].

An "immunological active component" as used herein means a component that induces or stimulates the immune response in an animal to which said component is administered. According to a preferred embodiment, said immune response is directed to said component or to a microorganism comprising said component. According to a further preferred embodiment, the immunological active component is an attenuated microorganism, including modified live virus (MLV), a killed-microorganism or at least an immunological active part of a microorganism.

"Immunological active part of a microorganism" as used herein means a protein-, sugar-, and or glycoprotein containing fraction of a microorganism that comprises at least one antigen that induces or stimulates the immune response in an animal to which said component is administered. According to a preferred embodiment, said immune response is directed to said immunological active part of a microorganism or to a microorganism comprising said immunological active part.

Preferably the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (41) or is an immunological active component of the swine pathogen (41).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (37) or is an immunological active component of the swine pathogen (37).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (1) or is an immunological active component of the swine pathogen (1).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (7) or is an immunological active component of the swine pathogen (7).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (24) or is an immunological active component of the swine pathogen (24).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (38) or is an immunological active component of the swine pathogen (38).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (21) or is an immunological active component of the swine pathogen (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (40) or is an immunological active component of the swine pathogen (40).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (2) or is an immunological active component of the swine pathogen (2).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (44) or is an immunological active component of the swine pathogen (44).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (50) or is an immunological active component of the swine pathogen (50).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (19), preferably (20) and/or (21) or is an immunological active component of the swine pathogen (19), preferably (20) and/or (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogen (22) or is an immunological active component of the swine pathogen (22).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (41) and (37), or is an immunological active component of the swine pathogens (41) and (37).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (1) and (41), or is an immunological active component of the swine pathogens (1) and (41).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (1) and (37), or is an immunological active component of the swine pathogens (1) and (37).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens, (1) (41) and (37), or is an immunological active component of the swine pathogens), (1), (41) and (37). In a preferred form, this combination is adjuvanted with Carbopol.

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (1) and (21), or is an immunological active component of the swine pathogens (1) and (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (21) and (41), or is an immunological active component of the swine pathogens (21) and (41).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (21) and (37), or is an immunological active component of the swine pathogens (21) and (37).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (21) and (38), or is an immunological active component of the swine pathogens (21) and (38).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (7) and (19), or is an immunological active component of the swine pathogens (7) and (19).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (38) and (33), preferably (34), (35) and/or (36), or is an immunological active component of the swine pathogens (38) and (33) preferably (34), (35) and/or (36).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (49), preferably (50), and (21), or is an immunological active component of the swine pathogens (49) preferably (50), and (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (49) preferably (50), (20) and (21), or is an immunological active component of the swine pathogens (49) preferably (50), (20) and (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (49) preferably (50), (20) and (21), or is an immunological active component of the swine pathogens (49) preferably (50), (20) and (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (49), preferably (50), (20), (38) and (21), or is an immunological active component of the swine pathogens (49), preferably (50), (20), (38) and (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (49) preferably (50), (20), (33) and (21), or is an immunological active component of the swine pathogens (49) preferably (50), (20) (33) and (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (49), preferably (50), (20), (38) (33) and (21), or is an immunological active component of the swine pathogens (49), preferably (50), (20), (38), (33) and (21).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (41), (40), and (19), or is an immunological active component of the swine pathogens (41), (40), and (19).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (38), (4), and (19), or is an immunological active component of the swine pathogens (38), (4), and (19).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (38), (4), (21), and (19), or is an immunological active component of the swine pathogens (38), (4), (21) and (19).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (20), preferably, (20), (31) and (38), or is an immunological active component of the swine pathogens (20), (31), (38).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (5), preferably, (5) and (24), or is an immunological active component of the swine pathogens (5), and (24).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (1), preferably, (1), and (5), or is an immunological active component of the swine pathogens (1), and (5).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (41), preferably, (40), (27), (28), (29), (31), (19) and (59), or is an immunological active component of the swine pathogens (41), (40), (27), (28), (29), (31), (19) and (57).

According to another aspect, the further immunological active component of [combo 1] is effective for the treatment and/or prophylaxis of infections caused by the swine pathogens (6), preferably, (6), (19), (38) and (58) or is an immunological active component of the swine pathogens (1), and (5).

According to a further aspect, the further immunological active component of the combination vaccine is selected from the group consisting Enterisol® Ileitis, Enterisol® Ileitis FF, Enterisol® SC-54, Enterisol® SC-54 FF, Enterisol® ERY-ALC, Ingelvac® APP ALC, Ingelvac® AR4, Ingelvac® HP-1, Ingelvac® HPE-1, Ingelvac® M. hyo, Ingelvac® PRRS MLV, Ingelvac® PRRS ATP, Ingelvac® PRV-G1, Reprocyc® PRRS PLE, Reprocyc® PLE, Tetguard™, Toxivac® AD+E, Toxivac® Plus Parsius, (all of Boehringer Ingelheim, St. Joseph, Mo., USA); Circovent, Porcilis Coli, Porcilis ERY+PARVO, Porcilis Ery, Porcilis Glasser, Porcilis Parvo, Porcilis Porcoli DF, Porcilis APP, Porcilis AR-T, Porcilis AR-T DF, Porcilis Porcoli, Porcilis Porcoli Diluvac forte, Porcilis PRRS, Porcilis Porcol 5, Porcilis Aujeszky, Porcilis Begonia Diluvac, Porcilis Begonia I.D.A.L., Porcilis Begonia Unisole, Porcilis M. hyo, Porcilis Atrinord, Myco Silencer® BPM, Myco Silencer® BPME, Myco Silencer® ME, Myco Silencer® M, Myco Silencer® Once, Myco Silencer®MEH, Rhinogen® BPE, Rhinogen® CTE 5000, Rhinogen® CTSE, Score, Sow Bac® E II, Sow Bac® CE II, Sow Bac® TREC, ProSystem® CE, ProSystem® RCE, ProSystem® TREC, ProSystem® Pillmune, ProSystem® Rotamune® with Imugan® II, ProSystem® Rota, ProSystem® Rotamune KV, ProSystem® TG-Emune® Rota with Imugan® II, ProSystem® TGE/Rota, ProSystem® TG-Emune® with Imugen®, ProSystem® TGE, MaGESTIC 7, MaGESTIC 8, MaGESTic™ with Spur®, MaGESTic® 7 with Spur®, MaGESTic® 8 with Spur®, End-FLUence® with Imugen® II, End-FLUence® 2, PRRomiSE®, PRV-Begonia with Dlluvac Forte®, Argus® SC/ST, Strep Bac, Strep Bac® with Imugen® II, Colisorb, Heptavac, Lambivac, Porcovac plus, Erysorb Parvo all of Intervet Inc., Millsboro, Del., USA); Hyoresp, Circovac, Neocolipor, Parvoruvac, Parvosuin, Progressis, Viraflu, Akipor 6.3, Jespur gl-, Jesflu gl- (all of Merial LTD, Duluth, Ga.); ER BAC® PLUS, ER BAC®, ER BAC® PLUS/LEPTOFERM-5®, ER BAC® Leptoferm-5®, Farrowsure®, Farrowsure® B, FARROWSURE® PLUS B, FARROWSURE® PLUS, FARROWSURE® PRV, FARROWSURE B-PRV, FLUSURE™, FLUSURE™ RTU, FLUSURE™/ER BAC® PLUS, FLUSURE™/ER BAC PLus®, FLUSURE™/RESPISURE®, FLUSURE™/RESPISURE® RTU, FLUSURE™/RESPISURE-ONE®/ER BAC® PLUS, FLUSURE□/RespiSure 1 ONE®/ER BAC Plus®, FLUSURE™/RESPISURE ONE®, FLUSURE□/RESPISURE 1 ONE®, FLUSURE/Farrowsure Plus, FLUSURE/Farrowsure Plus B, LITTERGUARD® LT-C, LITTERGUARD® LT, PleuroGuard® 4, Pneumosuis III, Stellamune One, Stellamune Uno, Stellamune Once, Stellamune Mono, Stellamune *Mycoplasma*, Respisure One, Respisure®, Respisure 1 ONE®, Respisure 1 One®/ER Bac Plus®, Enduracell T, Zylexis (formerly known as Baypamune), Atrobac® 3, BratiVac®, BratiVac®-B, Leptoferm-5^{oo} Parvo-Vac®/Leptoferm-5®, PR-Vac®-Killed, PR-Vac®, PR-Vac Plus™ (all of Pfizer Inc., New York, N.Y., USA); Suvaxyn MH One, Suvaxyn RespiFend® MH, Suvaxyn *Mycoplasma*, Suvaxyn Aujeszky Bartha+Diluent, Suvaxyn Aujeszky Bartha+o/w, Suvaxyn Aujeszky-Flu, Suvaxyn Aujeszky 783+o/w, Suvaxyn Ery, Suvaxyn Flu, Suvaxyn M. hyo, Suvaxyn MH-One, Suvaxyn Parvo ST, Suvaxyn Parvo/E, Suvaxyn RespiFend® APP, Suvaxyn RespiFend® HPS, Suvaxyn RespiFend® MH/HPS, Suvaxyn RespiFend® MH, Suvaxyn® AR/T/E, Suvaxyn® EC-4, Suvaxyn® E, Suvaxyn®-E, Suvaxyn® E-oral, Suvaxyn® PLE, Suvaxyn® PLE/PrV gpl-, Suvaxyn® LE+B, Suvaxyn® PLE+B, Suvaxyn® PLE+B/PrV gpl-, Suvaxyn® SIV, Suvaxyn® SIV/Mh-one, Suvaxyn® P, Suvaxyn® PrV gpl-, Suvaxyn® PCV-2 One Shot (all of Fort Dodge Animal Health, Overland Park, Kans., USA (Wyeth); SCOURMUNE®, SCOURMUNE®-C, SCOURMUNE®-CR, AR-PAC®-PD+ER, AR-PARAPAC®+ER, M+Rhusigen®, M+PAC®, MaxiVac Excell®3, MaxiVac® H1N1, MaxiVac® H3N2, MaxiVac®-FLU, MaxiVac®-M+, MaxiVac Excell®, MaxiVac Excell 3, PARAPAC®, PNEU PAC®, PNEU PAC®-ER, PNEU PAC®+ER, PRV/Marker Gold®, PRV/Marker Gold®, PRV/Marker Gold®-MaxiVac® FLU, Rhusigen™, Gletvax 6, Covexin 8, M+PAC, Gletvax plus, M-Parapac™ SS PAC® (all of Schering-Plough Animal Health Corporation, Kenilworth, N.J., USA); AMERVAC-PRRS, AUSKIPRA-BK, AUSKIPRA-GN, COLISUIN-CL, COLISUIN-TP, ERYSIPRAVAC, GRIPORK, HIPRASUIS-GLÄSSER, MYPRAVAC SUIS, NEUMOSUIN, PARVOSUIN, PARVOSUIN-MR, PARVOSUIN-MR/AD, RINIPRAVAC-DT, SUIPRAVAC-PRRS, SUIPRAVAC-RC, TOXIPRA PLUS (all of Laboratorios Hipra S.A., Amer, Girona, Spain); Clostricol, Coliporc Plus, Haeppovac, Per-C-Porc, Porciparvac, RESPIPORC ART+EP, RESPIPORC FLU, Respiporc M. HYO 1 SHOT, Rhusiovac, Rotlauf-Lebendimpfstoff, Salmoporc, Suisaloral, AK-vac MK35 (all of IDT Impfstoffwerk DessaTornau, Tornau, Germany); Mypravac Suis, (Albrecht GmbH, Germany); Haemo Shield® P, Parapleuro Shield® P, Parapleuro Shield® P+BE,

Rhinicell®FD, Rhini Shield™ TX4, Prefarrow Shield® 9, Prefarrow Strep Shield®, Clostratox® BCD, Clostratox® C, Clostratox® Ultra C 1300, Porcine Ecolizer® 3+C, Porcine Pili Shield™+C, Porcine Pili Shield™ Porcine Ecolizer® 3, Ery Serum™ Ery Shield™ Ery Vac Oral, Ery Shield™+L5, PanSTAR™ Ery, Erycell™ Parvo Shield® E, Parvo Shield® L5E, Parvo Shield® L5, Parvo Shield®, Para Shield®, PneumoSTAR SIV, PneumoSTAR™ Myco, Lepto Shield™ 5, Myco Shield™ Salmo Shield® 2, Salmo Shield® Live, Amitox Tet™ C. Perfingens Type A Toxoid (all of Novartis Animal Health, Basel, Switzerland); Nitro-Sal (Akro); or any antigen which in included in the compositions described above. Alternatively, when PCV2 antigen is already present in any of those vaccines, (i) PCV2 antigen, as described herein, is added to any of those compostions/antigens, or (ii) the PCV2 antigen present in any of those vaccines is replaced by the PCV2 antigen, as described herein.

According to further aspect, the further immunological active component of the combination vaccine is selected from the group consisting Enterisol® Ileitis, Enterisol® Ileitis FF, Enterisol® SC-54, Enterisol® SC-54 FF, Enterisol® ERY-ALC, Ingelvac® APP ALC, Ingelvac® AR4, Ingelvac® HP-1, Ingelvac® HPE-1, Ingelvac® M. hyo, Ingelvac®PRRS MLV, Ingelvac® PRRS ATP, Ingelvac® PRV-G1, Reprocyc® PRRS PLE, Reprocyc® PLE, Tetguard™, Toxivac® AD+E, Toxivac® Plus Parsius, (all of Boehringer Ingelheim, St. Joseph, Mo., USA); Circovent, Porcilis Coli, Porcilis ERY+PARVO, Porcilis Ery, Porcilis Glasser, Porcilis Parvo, Porcilis Porcoli DF, Porcilis APP, Porcilis AR-T, Porcilis AR-T DF, Porcilis Porcoli, Porcilis Porcoli Diluvac forte, Porcilis PRRS, Porcilis Porcol 5, Porcilis Aujeszky, Porcilis Begonia Diluvac, Porcilis Begonia I.D.A.L., Porcilis Begonia Unisole, Porcilis M. hyo, Porcilis Atrinord, Myco Silencer® BPM, Myco Silencer® BPME, Myco Silencer® ME, Myco Silencer® M, Myco Silencer® Once, Myco Silencer® MEH, Rhinogen® BPE, Rhinogen® CTE 5000, Rhinogen® CTSE, Score, Sow Bac® E II, Sow Bac® CE II, Sow Bac® TREC, ProSystem® CE, ProSystem® RCE, ProSystem® TREC, ProSystem® Pillmune, ProSystem® Rotamune® with Imugan® II, ProSystem® Rota, ProSystem® Rotamune KV, ProSystem® TG-Emune® Rota with Imugan® II, ProSystem® TGE/Rota, ProSystem® TG-Emune® with Imugen®, ProSystem® TGE, MaGESTIC 7, MaGESTIC 8, MaGESTic™ with Spur®, MaGESTic® 7 with Spur®, MaGESTic® 8 with Spur®, End-FLUence® with Imugen® Il, End-FLUence® 2, PRRomiSE®, PRV-Begonia with Dlluvac Forte®, Argus® SC/ST, Strep Bac, Strep Bac® with Imugen® II, Colisorb, Heptavac, Lambivac, Porcovac plus, Erysorb Parvo all of Intervet Inc., Millsboro, Del., USA); Hyoresp, Circovac, Neocolipor, Parvoruvac, Parvosuin, Progressis, Viraflu, Akipor 6.3, Jespur gl-, Jesflu gl-(all of Merial LTD, Duluth, Ga.); ER BAC® PLUS, ER BAC®, ER BAC® PLUS/LEPTOFERM-5®, ER BAC® Leptoferm-5®, Farrowsure®, Farrowsure® B, FARROWSURE® PLUS B, FARROWSURE® PLUS, FARROWSURE® PRV, FARROWSURE B-PRV, FLUSURE™, FLUSURE™ RTU, FLUSURE™/ER BAC® PLUS, FLUSURE™/ER BAC PLus®, FLUSURE™/RESPISURE®, FLUSURE™/RESPISURE® RTU, FLUSURE™/RESPISURE-ONE®/ER BAC® PLUS, FLUSURE□/RespiSure 1 ONE®/ER BAC Plus®, FLUSURE™/RESPISURE ONE®, FLUSURE□/RESPISURE 1 ONE®, FLUSURE/Farrowsure Plus, FLUSURE/Farrowsure Plus B, LITTERGUARD® LT-C, LITTERGUARD® LT, PleuroGuard® 4, Pneumosuis III, Stellamune One, Stellamune Uno, Stellamune Once, Stellamune Mono, Stellamune *Mycoplasma*, Respisure One, Respisure®, Respisure 1 ONE®, Respisure 1 One®/ER Bac Plus®, Enduracell T, Zylexis (formerly known as Baypamune), Atrobac® 3, BratiVac®, BratiVac®-B, Leptoferm-5°°.Parvo-Vac®/Leptoferm-5®, PR-Vac®-Killed, PR-Vac®, PR-Vac Plus™ (all of Pfizer Inc., New York, N.Y., USA); Suvaxyn MH One, Suvaxyn RespiFend® MH, Suvaxyn *Mycoplasma*, Suvaxyn Aujeszky Bartha+Diluent, Suvaxyn Aujeszky Bartha+o/w, Suvaxyn Aujeszky-Flu, Suvaxyn Aujeszky 783+o/w, Suvaxyn Ery, Suvaxyn Flu, Suvaxyn M. hyo, Suvaxyn MH-One, Suvaxyn Parvo ST, Suvaxyn Parvo/E, Suvaxyn RespiFend® APP, Suvaxyn RespiFend® HPS, Suvaxyn RespiFend® MH/HPS, Suvaxyn RespiFend® MH, Suvaxyn® AR/T/E, Suvaxyn® EC-4, Suvaxyn® E, Suvaxyn®-E, Suvaxyn® E-oral, Suvaxyn® PLE, Suvaxyn® PLE/PrV gpl-, Suvaxyn® LE+B, Suvaxyn®PLE+B, Suvaxyn® PLE+B/PrV gpl-, Suvaxyn® SIV, Suvaxyn® SIV/Mh-one, Suvaxyn® P, Suvaxyn® PrV gpl-, Suvaxyn® PCV-2 One Shot (all of Fort Dodge Animal Health, Overland Park, Kans., USA (Wyeth); SCOURMUNE®, SCOURMUNE®-C, SCOURMUNE®-CR, AR-PAC®-PD+ER, AR-PARAPAC®+ER, M+Rhusigen®, M+PAC®, MaxiVac Excell®3, MaxiVac® H1N1, MaxiVac® H3N2, MaxiVac®-FLU, MaxiVac®-M+, MaxiVac Excell®, MaxiVac Excell 3, PARAPAC®, PNEU PAC®, PNEU PAC®-ER, PNEU PAC®+ER, PRV/Marker Gold®, PRV/Marker Gold®, PRV/Marker Gold®-MaxiVac® FLU, Rhusigen™, Gletvax 6, Covexin 8, M+PAC, Gletvax plus, M-Parapac™ SS PAC® (all of Schering-Plough Animal Health Corporation, Kenilworth, N.J., USA); AMERVAC-PRRS, AUSKIPRA-BK, AUSKIPRA-GN, COLISUIN-CL, COLISUIN-TP, ERYSIPRAVAC, GRIPORK, HIPRASUIS-GLÄSSER, MYPRAVAC SUIS, NEUMOSUIN, PARVOSUIN, PARVOSUIN-MR, PARVOSUIN-MR/AD, RINIPRAVAC-DT, SUIPRAVAC-PRRS, SUIPRAVAC-RC, TOXIPRA PLUS (all of Laboratorios Hipra S.A., Amer, Girona, Spain); Clostricol, Coliporc Plus, Haeppovac, Per-C-Pore, Porciparvac, RESPIPORC ART+EP, RESPIPORC FLU, Respiporc M. HYO 1 SHOT, Rhusiovac, Rotlauf-Lebendimpfstoff, Salmoporc, Suisaloral, AK-vac MK35 (all of IDT Impfstoffwerk DessaTornau, Tornau, Germany); Mypravac Suis, (Albrecht GmbH, Germany); Haemo Shield® P, Parapleuro Shield® P, Parapleuro Shield® P+BE, Rhinicell® FD, Rhini Shield™ TX4, Prefarrow Shield® 9, Prefarrow Strep Shield®, Clostratox® BCD, Clostratox® C, Clostratox® Ultra C 1300, Porcine Ecolizer® 3+C, Porcine Pili Shield™+C, Porcine Pili Shield™ Porcine Ecolizer® 3, Ery Serum™ Ery Shield™ Ery Vac Oral, Ery Shield™+L5, PanSTAR™ Ery, Erycell™ Parvo Shield® E, Parvo Shield® L5E, Parvo Shield® L5, Parvo Shield®, Para Shield®, PneumoSTAR SIV, PneumoSTAR™ Myco, Lepto Shield™ 5, Myco Shield™ Salmo Shield® 2, Salmo Shield® Live, Amitox Tet™ C. Perfingens Type A Toxoid (all of Novartis Animal Health, Basel, Switzerland); Nitro-Sal (Akro); or any antigen which in included in the compositions described above. Alternatively, when PCV2 antigen is already present in any of those vaccines, (i) PCV2 antigen, as described herein, is added to any of those compostions/antigens, or (ii) the PCV2 antigen present in any of those vaccines is replaced by the PCV2 antigen, as described herein.

Formulations

An important aspect of the present invention is the preparation of the combination vaccine(s). The skilled person knows additional components which may be comprised in said composition (see also Remington's Pharmaceutical Sciences. (1990). 18th ed. Mack Publ., Easton). The expert may use known injectable, physiologically acceptable, sterile solutions. For preparing a ready-to-use solution for parenteral injection or infusion, aqueous isotonic solutions, such as e.g.

saline or corresponding plasma protein solutions, are readily available. The pharmaceutical compositions may be present as lyophylisates or dry preparations, which can be reconstituted with a known injectable solution directly before use under sterile conditions, e.g. as a kit of parts.

In addition, the immunogenic and vaccine compositions of the present invention can include one or more veterinary-acceptable carriers. As used herein, "a veterinary-acceptable carrier" includes any and all solvents, dispersion media, coatings, adjuvants, stabilizing agents, diluents, preservatives, antibacterial and antifungal agents, isotonic agents, adsorption delaying agents, and the like.

Diluents can include water, saline, dextrose, ethanol, glycerol, and the like. Isotonic agents can include sodium chloride, dextrose, mannitol, sorbitol, and lactose, among others. Stabilizers include albumin and alkali salts of ethylendiamintetracetic acid, among others.

Preferred adjuvants are those as described above. The immunogenic compositions can further include one or more other immunomodulatory agents such as, e.g., interleukins, interferons, or other cytokines. The immunogenic compositions can also include Gentamicin and Merthiolate. While the amounts and concentrations of adjuvants and additives useful in the context of the present invention can readily be determined by the skilled artisan, the present invention contemplates compositions comprising from about 50 ug to about 2000 ug of adjuvant and preferably about 250 ug/ml dose of the vaccine composition. In another preferred embodiment, the present invention contemplates vaccine compositions comprising from about 1 ug/ml to about 60 ug/ml of antibiotics, and more preferably less than about 30 ug/ml of antibiotics.

According to a further embodiment the combination vaccine is first dehydrated. If the composition is first lyophilized or dehydrated by other methods, then, prior to vaccination, said composition is rehydrated in aqueous (e.g. saline, PBS (phosphate buffered saline)) or non-aqueous solutions (e.g. oil emulsion (mineral oil, or vegetable/metabolizable oil based/single or double emulsion based), aluminum-based, carbomer based adjuvant).

Dosage and Administration

According to the present invention, an effective amount of a combination vaccine administered to pigs provides effective immunity against microbiological infections caused by PCV2 and at least one further pathogen as listed above. Preferred combinations of antigens for the treatment and prophylaxis of microbiological diseases in pigs are listed above.

According to a further embodiment, the combination vaccine is administered to pigs in one or two doses at an interval of about 2 to 4 weeks. For example, the first administration is performed when the animal is about 2 to 3 weeks to about 8 weeks of age. The second administration is performed about 1 to about 4 weeks after the first administration of the first vaccination. According to a further embodiment, revaccination is performed in an interval of 3 to 12 month after administration of the second dose. Administration of subsequent vaccine doses is preferably done on a 6 month to an annual basis. In another preferred embodiment, animals vaccinated before the age of about 2 to 3 weeks should be revaccinated. Administration of subsequent vaccine doses is preferably done on an annual basis.

The amount of combination vaccine that is effective depends on the ingredients of the vaccine and the schedule of administration. Typically, when an inactivated virus or a modified live virus preparation is used in the combination vaccine, an amount of the vaccine containing about 10^2 to about 10^9 $TCID_{50}$ per dose, preferably about 10^3 to about 10^8 $TCID_{50}$ per dose, more preferably, about 10^4 to about 10^8 $TCID_{50}$ per dose. In general, inactivated antigen is normally used in higher amounts than live modivied viruses. Typically, when bacterial antigen is used in the combination vaccine, the vaccine containing an amount of about 10^3 to about 10^9 colony forming units (CFU) per dose, preferably, about 10^4 to about 10^8 (CFU) per dose, more preferably about 10^5 to about 10^6 (CFU) per dose. Sub-unit vaccines are normally administered with an antigen inclusion level of at least 0.2 μg antigen per dose, preferably with about 0.2 to about 400 μg/dose, still more preferably with about 0.3 to about 200 μg/dose, even more preferably with about 0.35 to about 100 μg/dose, still more preferably with about 0.4 to about 50 μg/dose, still more preferably with about 0.45 to about 30 μg/dose, still more preferably with about 0.6 to about 15 μg/dose, even more preferably with about 0.75 to about 8 μg/dose, even more preferably with about 1.0 to about 6 μg/dose, and still more preferably with about 1.3 to about 3.0 μg/dose. For example, the antigen inclusion level of the PCV ORF2 antigen, preferably of the PCV2 ORF2 protein as provided herewith, contains about 2 μg to about 150 μg, preferably about 2 μg to about 60 μg, even more preferably about 2 μg to about 50 μg, even more preferably about 2 μg to about 40 μg, even more preferably about 2 μg to about 30 μg, even more preferably about 2 μg to about 25 μg, even more preferably about 2 μg to about 20 μg, even more preferably about 4 μg to about 20 μg, and even more preferably about 4 μg to about 16 μg. In the case of combination vaccines that include (37), it is preferred to use at least 1 to 10 logs, more preferably, 5-10 logs, and most preferably, 6-8 logs. In the case of combination vaccines that include (41), it is preferred to use at least 1 to 10 logs, more preferably, 3-10 logs, and most preferably, 5-6 logs.

The composition according to the invention may be applied intradermally, intratracheally, or intravaginally. The composition preferably may be applied intramuscularly or intranasally. In an animal body, it can prove advantageous to apply the pharmaceutical compositions as described above via an intravenous injection or by direct injection into target tissues. For systemic application, the intravenous, intravascular, intramuscular, intranasal, intraarterial, intraperitoneal, oral, or intrathecal routes are preferred. A more local application can be effected subcutaneously, intradermally, intracutaneously, intracardially, intralobally, intramedullarly, intrapulmonarily or directly in or near the tissue to be treated (connective-, bone-, muscle-, nerve-, epithelial tissue). Depending on the desired duration and effectiveness of the treatment, the compositions according to the invention may be administered once or several times, also intermittently, for instance on a daily basis for several days, weeks or months, and in different dosages.

Methods for Treatment

Yet another important embodiment of the invention is a method for the prophylaxis or treatment of diseases caused by PCV2, and one or more swine pathogenic microorganism(s), wherein a PCV2 antigen, preferably a PCV2 ORF2 protein as provided herewith, and further immunological active components effective for the treatment and/or prophylaxis of the infection caused by said further swine pathogenic microorganism is administered to an animal in need thereof at a suitable dosage. According to a further aspect, said PCV2 ORF2 protein, is part of an antigenic composition, as described above. Thus, yet another aspect of the present invention relates to a combination vaccine that comprises any one of the antigenic compositions provided herewith and that comprises PCV2 ORF2 protein, and another immunological

active component effective for the treatment and/or prophylaxis of an infection caused by said other swine pathogenic microorganism.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic flow diagram of a preferred construction of PCV2 ORF2 recombinant baculovirus; and

FIGS. **2***a* and **2***b* are each a schematic flow diagram of how to produce a composition in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following examples set forth preferred materials and procedures in accordance with the present invention. It is to be understood, however, that these examples are provided by way of illustration only, and nothing therein should be deemed a limitation upon the overall scope of the invention.

EXAMPLE 1

This example compares the relative yields of ORF2 using methods of the present invention with methods that are known in the prior art. Four 1000 mL spinner flasks were each seeded with approximately 1.0×10^6 Sf+ cells/ml in 300 mL of insect serum free media, Excell 420 (JRH Biosciences, Inc., Lenexa, Kans.). The master cell culture is identified as SF+ (*Spodoptera frugiperda*) Master Cell Stock, passage 19, Lot#N112-095W. The cells used to generate the SF+Master Cell Stock were obtained from Protein Sciences Corporation, Inc., Meriden, Conn. The SF+ cell line for this example was confined between passages 19 and 59. Other passages will work for purposes of the present invention, but in order to scale the process up for large scale production, at least 19 passages will probably be necessary and passages beyond 59 may have an effect on expression, although this was not investigated. In more detail, the initial SF+ cell cultures from liquid nitrogen storage were grown in Excell 420 media in suspension in sterile spinner flasks with constant agitation. The cultures were grown in 100 mL to 250 mL spinner flasks with 25 to 150 mL of Excell 420 serum-free media. When the cells had multiplied to a cell density of $1.0–8.0\times10^6$ cells/mL, they were split to new vessels with a planting density of $0.5–1.5\times10^6$ cells/mL. Subsequent expansion cultures were grown in spinner flasks up to 36 liters in size or in stainless steel bioreactors of up to 300 liters for a period of 2-7 days at 25-29° C.

After seeding, the flasks were incubated at 27° C. for four hours. Subsequently, each flask was seeded with a recombinant baculovirus containing the PCV2 ORF2 gene (SEQ ID NO: 4). The recombinant baculovirus containing the PCV2 ORF2 gene was generated as follows: the PCV2 ORF2 gene from a North American strain of PCV2 was PCR amplified to contain a 5' Kozak's sequence (SEQ ID NO: 1) and a 3' EcoR1 site (SEQ ID NO: 2), cloned into the pGEM-T-Easy vector (Promega, Madison, Wis.). Then, it was subsequently excised and subcloned into the transfer vector pVL1392 (BD Biosciences Pharmingen, San Diego, Calif.). The subcloned portion is represented herein as SEQ ID NO: 7. The pVL1392 plasmid containing the PCV2 ORF2 gene was designated N47-064Y and then co-transfected with BaculoGold® (BD Biosciences Pharmingen) baculovirus DNA into Sf+ insect cells (Protein Sciences, Meriden, Conn.) to generate the recombinant baculovirus containing the PCV2 ORF2 gene. The new construct is provided herein as SEQ ID NO: 8. The recombinant baculovirus containing the PCV2 ORF2 gene was plaque-purified and Master Seed Virus (MSV) was propagated on the SF+ cell line, aliquotted, and stored at −70° C. The MSV was positively identified as PCV2 ORF2 baculovirus by PCR-RFLP using baculovirus specific primers. Insect cells infected with PCV2 ORF2 baculovirus to generate MSV or Working Seed Virus express PCV2 ORF2 antigen as detected by polyclonal serum or monoclonal antibodies in an indirect fluorescent antibody assay. Additionally, the identity of the PCV2 ORF2 baculovirus was confirmed by N-terminal amino acid sequencing. The PCV2 ORF2 baculovirus MSV was also tested for purity in accordance with 9 C.F.R. 113.27 (c), 113.28, and 113.55. Each recombinant baculovirus seeded into the spinner flasks had varying multiplicities of infection (MOIs). Flask 1 was seeded with 7.52 mL of 0.088 MOI seed; flask 2 was seeded with 3.01 mL of 0.36MOI seed; flask 3 was seeded with 1.5 mL of 0.18MOI seed; and flask 4 was seeded with 0.75 mL of 0.09MOI seed. A schematic flow diagram illustrating the basic steps used to construct a PCV2 ORF2 recombinant baculovirus is provided herein as FIG. **1**.

After being seeded with the baculovirus, the flasks were then incubated at 27±2° C. for 7 days and were also agitated at 100 rpm during that time. The flasks used ventilated caps to allow for air flow. Samples from each flask were taken every 24 hours for the next 7 days. After extraction, each sample was centrifuged, and both the pellet and the supernatant were separated and then microfiltered through a 0.45-1.0 μm pore size membrane.

The resulting samples then had the amount of ORF2 present within them quantified via an ELISA assay. The ELISA assay was conducted with capture antibody Swine anti-PCV2 Pab IgG Prot. G purified (diluted 1:250 in PBS) diluted to 1:6000 in 0.05M Carbonate buffer (pH 9.6). 100 μL of the antibody was then placed in the wells of the mictrotiter plate, sealed, and incubated overnight at 37° C. The plate was then washed three times with a wash solution which comprised 0.5 mL of Tween 20 (Sigma, St. Louis, Mo.), 100 mL of 10×D-PBS (Gibco Invitrogen, Carlsbad, Calif.) and 899.5 mL of distilled water. Subsequently, 250 μL of a blocking solution (5 g Carnation Non-fat dry milk (Nestle, Glendale, Calif.) in 10 mL of D-PBS QS to 100 mL with distilled water) was added to each of the wells. The next step was to wash the test plate and then add pre-diluted antigen. The pre-diluted antigen was produced by adding 200 μL of diluent solution (0.5 mL Tween 20 in 999.5 mL D-PBS) to each of the wells on a dilution plate. The sample was then diluted at a 1:240 ratio and a 1:480 ratio, and 100 μL of each of these diluted samples was then added to one of the top wells on the dilution plate (i.e. one top well received 100 μL of the 1:240 dilution and the other received 100 μL of the 1:480 dilution). Serial dilutions were then done for the remainder of the plate by removing 100 μL form each successive well and transferring it to the next well on the plate. Each well was mixed prior to doing the next transfer. The test plate washing included washing the plate three times with the wash buffer. The plate was then sealed and incubated for an hour at 37° C. before being washed three more times with the wash buffer. The detection antibody used was monoclonal antibody to PCV ORF2. It was diluted to 1:300 in diluent solution, and 100 μL of the diluted detection antibody was then added to the wells. The plate was then sealed and incubated for an hour at 37° C. before being washed three times with the wash buffer. Conjugate diluent was then prepared by adding normal rabbit serum (Jackson Immunoresearch, West Grove, Pa.) to the diluent solution to 1% concentration. Conjugate antibody Goat anti-mouse (H+1)-HRP (Jackson Immunoresearch) was diluted in the conjugate diluent to 1:10,000. 100 μL of the

diluted conjugate antibody was then added to each of the wells. The plate was then sealed and incubated for 45 minutes at 37° C. before being washed three times with the wash buffer. 100 μL of substrate (TMB Peroxidase Substrate, Kirkgaard and Perry Laboratories (KPL), Gaithersberg, Md.), mixed with an equal volume of Peroxidase Substrate B (KPL) was added to each of the wells. The plate was incubated at room temperature for 15 minutes. 100 μL of 1N HCL solution was then added to all of the wells to stop the reaction. The plate was then run through an ELISA reader. The results of this assay are provided in Table 1 below:

TABLE 1

Day	Flask	ORF2 in pellet (μg)	ORF2 in supernatant (μg)
3	1	47.53	12
3	2	57.46	22
3	3	53.44	14
3	4	58.64	12
4	1	43.01	44
4	2	65.61	62
4	3	70.56	32
4	4	64.97	24
5	1	31.74	100
5	2	34.93	142
5	3	47.84	90
5	4	55.14	86
6	1	14.7	158
6	2	18.13	182
6	3	34.78	140
6	4	36.88	146
7	1	6.54	176
7	2	12.09	190
7	3	15.84	158
7	4	15.19	152

These results indicate that when the incubation time is extended, expression of ORF2 into the supernatant of the centrifuged cells and media is greater than expression in the pellet of the centrifuged cells and media. Accordingly, allowing the ORF2 expression to proceed for at least 5 days and recovering it in the supernate rather than allowing expression to proceed for less than 5 days and recovering ORF2 from the cells, provides a great increase in ORF2 yields, and a significant improvement over prior methods.

EXAMPLE 2

This example provides data as to the efficacy of the invention claimed herein. A 1000 mL spinner flask was seeded with approximately 1.0×10^6 Sf+ cells/ml in 300 mL of Excell 420 media. The flask was then incubated at 27° C. and agitated at 100 rpm. Subsequently, the flask was seeded with 10 mL of PCV2 ORF2/Bac p+6 (the recombinant baculovirus containing the PCV2 ORF2 gene passaged 6 additional times in the 519 insect cells) virus seed with a 0.1 MOI after 24 hours of incubation.

The flask was then incubated at 27° C. for a total of 6 days. After incubation, the flask was then centrifuged and three samples of the resulting supernatant were harvested and inactivated. The supernatant was inactivated by bringing its temperature to 37±2° C. To the first sample, a 0.4M solution of 2-bromoethyleneamine hydrobromide which had been cyclized to 0.2M binary ethlylenimine (BEI) in 0.3N NaOH is added to the supernatant to give a final concentration of BEI of 5 mM. To the second sample, 10 mM BEI was added to the supernatant. To the third sample, no BEI was added to the supernatant. The samples were then stirred continuously for 48 hrs. A 1.0 M sodium thiosulfate solution to give a final minimum concentration of 5 mM was added to neutralize any residual BEI. The quantity of ORF2 in each sample was then quantified using the same ELISA assay procedure as described in Example 1. The results of this may be seen in Table 2 below:

TABLE 2

Sample	ORF2 in supernatant (μg)
1	78.71
2	68.75
3	83.33

This example demonstrates that neutralization with BEI does not remove or degrade significant amounts of the recombinant PCV2 ORF2 protein product. This is evidenced by the fact that there is no large loss of ORF2 in the supernatant from the BEI or elevated temperatures. Those of skill in the art will recognize that the recovered ORF2 is a stable protein product.

EXAMPLE 3

This example demonstrates that the present invention is scalable from small scale production of recombinant PCV2 ORF2 to large scale production of recombinant PCV2 ORF2. 5.0×10^5 cells/ml of SF+ cells/ml in 7000 mL of ExCell 420 media was planted in a 20000 mL Applikon Bioreactor. The media and cells were then incubated at 27° C. and agitated at 100 RPM for the next 68 hours. At the 68^{th} hour, 41.3 mL of PCV2 ORF2 Baculovirus MSV+3 was added to 7000 mL of ExCell 420 medium. The resultant mixture was then added to the bioreactor. For the next seven days, the mixture was incubated at 27° C. and agitated at 100 RPM. Samples from the bioreactor were extracted every 24 hours beginning at day 4, post-infection, and each sample was centrifuged. The supernatant of the samples were preserved and the amount of ORF2 was then quantified using SDS-PAGE densitometry. The results of this can be seen in Table 3 below:

TABLE 3

Day after infection:	ORF2 in supernatant (μg/mL)
4	29.33
5	41.33
6	31.33
7	60.67

EXAMPLE 4

This example tests the efficacy of seven PCV2 candidate vaccines and further defines efficacy parameters following exposure to a virulent strain of PCV2. One hundred and eight (108) cesarean derived colostrum deprived (CDCD) piglets, 9-14 days of age, were randomly divided into 9 groups of equal size. Table 4 sets forth the General Study Design for this Example.

TABLE 4

General Study Design

Group	No. Of Pigs	Treatment	Day of Treatment	KLH/ICFA on Day 21 and Day 27	Challenged with Virulent PCV2 on Day 24	Necropsy on Day 49
1	12	PCV2 Vaccine No. 1 - (vORF2 16 μg)	0	+	+	+
2	12	PCV2 Vaccine No. 2 - (vORF2 8 μg)	0	+	+	+
3	12	PCV2 Vaccine No. 3 - (vORF2 4 μg)	0	+	+	+
4	12	PCV2 Vaccine No. 4 - (rORF2 16 μg)	0	+	+	+
5	12	PCV2 Vaccine No. 5 - (rORF2 8 μg)	0	+	+	+
6	12	PCV2 Vaccine No. 6 - (rORF2 4 μg)	0	+	+	+
7	12	PCV2 Vaccine No. 7 - (Killed whole cell virus)	0	+	+	+
8	12	None - Challenge Controls	N/A	+	+	+
9	12	None - Strict Negative Control Group	N/A	+	−	+

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
killed whole cell virus = PCV2 virus grown in suitable cell culture

Seven of the groups (Groups 1-7) received doses of PCV2 ORF2 polypeptide, one of the groups acted as a challenge control and received no PCV2 ORF2, and another group acted as the strict negative control group and also received no PCV2 ORF2. On Day 0, Groups 1 through 7 were treated with assigned vaccines. Piglets in Group 7 were given a booster treatment on Day 14. Piglets were observed for adverse events and injection site reactions following vaccination and on Day 19, piglets were moved to the second study site. At the second study site, Groups 1-8 were group housed in one building while Group 9 was housed in a separate building. All pigs received keyhole limpet hemocyanin (KLH)/incomplete Freund's adjuvant (ICFA) on Days 21 and 27 and on Day 24, Groups 1-8 were challenged with a virulent PCV2.

Pre- and post-challenge, blood samples were collected for PCV2 serology. Post-challenge, body weight data for determination of average daily weight gain (ADWG), and clinical symptoms, as well as nasal swab samples to determine nasal shedding of PCV2, were collected. On Day 49, all surviving pigs were necropsied, lungs were scored for lesions, and selected tissues were preserved in formalin for Immunohistochemistry (IHC) testing at a later date.

Materials and Methods

This was a partially blinded vaccination-challenge feasibility study conducted in CDCD pigs, 9 to 14 days of age on Day 0. To be included in the study, PCV2 IFA titers of sows were ≤1:1000. Additionally, the serologic status of sows were from a known PRRS-negative herd. Twenty-eight (28) sows were tested for PCV2 serological status. Fourteen (14) sows had a PCV2 titer of ≤1000 and were transferred to the first study site. One hundred ten (110) piglets were delivered by cesarean section surgeries and were available for this study on Day −4. On Day −3, 108 CDCD pigs at the first study site were weighed, identified with ear tags, blocked by weight and randomly assigned to 1 of 9 groups, as set forth above in table 4. If any test animal meeting the inclusion criteria was enrolled in the study and was later excluded for any reason, the Investigator and Monitor consulted in order to determine the use of data collected from the animal in the final analysis. The date of which enrolled piglets were excluded and the reason for exclusion was documented. Initially, no sows were excluded. A total of 108 of an available 110 pigs were randomly assigned to one of 9 groups on Day −3. The two smallest pigs (No. 17 and 19) were not assigned to a group and were available as extras, if needed. During the course of the study, several animals were removed. Pig 82 (Group 9) on Day −1, Pig No. 56 (Group 6) on Day 3, Pig No. 53 (Group 9) on Day 4, Pig No. 28 (Group 8) on Day 8, Pig No. 69 (Group 8) on Day 7, and Pig No. 93 (Group 4) on Day 9, were each found dead prior to challenge. These six pigs were not included in the final study results. Pig no 17 (one of the extra pigs) was assigned to Group 9. The remaining extra pig, No. 19, was excluded from the study.

The formulations given to each of the groups were as follows: Group 1 was designed to administer 1 ml of viral ORF2 (vORF2) containing 16 μg ORF2/ml. This was done by mixing 10.24 ml of viral ORF2 (256 μg/25 μg/ml=10.24 ml vORF2) with 3.2 ml of 0.5% Carbopol and 2.56 ml of phosphate buffered saline at a pH of 7.4. This produced 16 ml of formulation for group 1. Group 2 was designed to administer 1 ml of vORF2 containing 8 μg vORF2/ml. This was done by mixing 5.12 ml of vORF2 (128 μg/25 μg/ml=5.12 ml vORF2) with 3.2 ml of 0.5% Carbopol and 7.68 ml of phosphate buffered saline at a pH of 7.4. This produced 16 ml of formulation for group 2. Group 3 was designed to administer 1 ml of vORF2 containing 4 μg vORF2/ml. This was done by mixing 2.56 ml of vORF2 (64 μg/25 μg/ml=2.56 ml vORF2) with 3.2 ml of 0.5% Carbopol and 10.24 ml of phosphate buffered saline at a pH of 7.4. This produced 16 ml of formulation for group 3. Group 4 was designed to administer 1 ml of recombinant ORF2 (rORF2) containing 16 μg rORF2/ml. This was done by mixing 2.23 ml of rORF2 (512 μg/230 μg/ml=2.23 ml rORF2) with 6.4 ml of 0.5% Carbopol and 23.37 ml of phosphate buffered saline at a pH of 7.4. This produced 32 ml of formulation for group 4. Group 5 was designed to administer 1 ml of rORF2 containing 8 μg rORF2/ml. This was done by mixing 1.11 ml of rORF2 (256 μg/230 μg/ml=1.11 ml rORF2) with 6.4 ml of 0.5% Carbopol and 24.49 ml of phos-

phate buffered saline at a pH of 7.4. This produced 32 ml of formulation for group 5. Group 6 was designed to administer 1 ml of rORF2 containing 8 μg rORF2/ml. This was done by mixing 0.56 ml of rORF2 (128 μg/230 μg/ml=0.56 ml rORF2) with 6.4 ml of 0.5% Carbopol and 25.04 ml of phosphate buffered saline at a pH of 7.4. This produced 32 ml of formulation for group 6. Group 7 was designed to administer 2 ml of PCV2 whole killed cell vaccine (PCV2 KV) containing the MAX PCV2 KV. This was done by mixing 56 ml of PCV2 KV with 14 ml of 0.5% Carbopol. This produced 70 ml of formulation for group 7. Finally group 8 was designed to administer KLH at 0.5 μg/ml or 1.0 μg/ml per 2 ml dose. This was done by mixing 40.71 ml KLH (7.0 μg protein/ml at 0.5 μg/ml=570 ml (7.0 μg/ml)(x)=(0.5)(570 ml)), 244.29 ml phosphate buffered saline at a pH of 7.4, and 285 ml Freunds adjuvant. Table 5 describes the time frames for the key activities of this Example.

TABLE 5

Study Activities

Study Day	Study Activity
−4, 0 to 49	General observations for overall health and clinical symptoms
−3	Weighed; Randomized to groups; Collected blood samples from all pigs
0	Health examination; Administered IVP Nos. 1-7 to Groups 1-7, respectively
0-7	Observed pigs for injection site reactions
14	Boostered Group 7 with PCV2 Vaccine No. 7; Blood samples from all pigs
14-21	Observed Group 7 for injection site reactions
16-19	Treated all pigs with antibiotics (data missing)
19	Pigs transported from the first test site to a second test site
21	Treated Groups 1-9 with KLH/ICFA
24	Collected blood and nasal swab samples from all pigs; Weighed all pigs; Challenged Groups 1-8 with PCV2 challenge material
25, 27, 29, 31, 33, 35, 37, 39, 41, 43, 45, 47	Collected nasal swab samples from all pigs
27	Treated Groups 1-9 with KLH/ICFA
31	Collected blood samples from all pigs
49	Collected blood and nasal swab samples from all pigs; Weighed all pigs; Necropsy all pigs; Gross lesions noted with emphasis placed on icterus and gastric ulcers; Lungs evaluated for lesions; Fresh and formalin fixed tissue samples saved; In-life phase of the study completed

Following completion of the in-life phase of the study, formalin fixed tissues were examined by Immunohistochemistry (IHC) for detection of PCV2 antigen by a pathologist, blood samples were evaluated for PCV2 serology, nasal swab samples were evaluated for PCV2 shedding, and average daily weight gain (ADWG) was determined from Day 24 to Day 49.

Animals were housed at the first study site in individual cages in five rooms from birth to approximately 11 days of age (approximately Day 0 of the study). Each room was identical in layout and consisted of stacked individual stainless steel cages with heated and filtered air supplied separately to each isolation unit. Each room had separate heat and ventilation, thereby preventing cross-contamination of air between rooms. Animals were housed in two different buildings at the second study site. Group 9 (The Strict negative control group) was housed separately in a converted finisher building and Groups 1-8 were housed in converted nursery building. Each group was housed in a separate pen (11-12 pigs per pen) and each pen provided approximately 3.0 square feet per pig. Each pen was on an elevated deck with plastic slatted floors. A pit below the pens served as a holding tank for excrement and waste. Each building had its own separate heating and ventilation systems, with little likelihood of cross-contamination of air between buildings.

At the first study site, piglets were fed a specially formulated milk ration from birth to approximately 3 weeks of age. All piglets were consuming solid, special mixed ration by Day 19 (approximately 4½ weeks of age). At the second study site, all piglets were fed a custom non-medicated commercial mix ration appropriate for their age and weight, ad libitum. Water at both study sites was also available ad libitum.

All test pigs were treated with Vitamin E on Day −2, with iron injections on Day −1 and with NAXCEL® (1.0 mL, IM, in alternating hams) on Days 16, 17, 18 and 19. In addition, Pig No. 52 (Group 9) was treated with an iron injection on Day 3, Pig 45 (Group 6) was treated with an iron injection on Day 11, Pig No. 69 (Group 8) was treated with NAXCEL® on Day 6, Pig No. 74 (Group 3) was treated with dexamethazone and penicillin on Day 14, and Pig No. 51 (Group 1) was treated with dexamethazone and penicillin on Day 13 and with NAXCEL® on Day 14 for various health reasons.

While at both study sites, pigs were under veterinary care. Animal health examinations were conducted on Day 0 and were recorded on the Health Examination Record Form. All animals were in good health and nutritional status before vaccination as determined by observation on Day 0. All test animals were observed to be in good health and nutritional status prior to challenge. Carcasses and tissues were disposed of by rendering. Final disposition of study animals was records on the Animal Disposition Record.

On Day 0, pigs assigned to Groups 1-6 received 1.0 mL of PCV2 Vaccines 1-6, respectively, 1M in the left neck region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×½" needle. Pigs assigned to Group 7 received 2.0 mL of PCV2 Vaccine No. 7 IM in the left neck region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×½" needle. On Day 14, pigs assigned to Group 7 received 2.0 mL of PCV2 Vaccine No. 7 IM in the right neck region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×½" needle.

On Day 21 all test pigs received 2.0 mL of KLH/ICFA IM in the right ham region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×1" needle. On Day 27 all test pigs received 2.0 mL of KLH/ICFA in the left ham region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×1" needle.

On Day 24, pigs assigned to Groups 1-8 received 1.0 mL of PCV2 ISUVDL challenge material (5.11 $\log_{10}$ $TCID_{50}$/mL) IM in the left neck region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×1" needle. An additional 1.0 mL of the same material was administered IN to each pig (0.5 mL per nostril) using a sterile 3.0 mL Luer-lock syringe and nasal canula.

Test pigs were observed daily for overall health and adverse events on Day −4 and from Day 0 to Day 19. Observations were recorded on the Clinical Observation Record. All test pigs were observed from Day 0 to Day 7, and Group 7 was further observed from Day 14 to 21, for injection site reactions. Average daily weight gain was determined by weighing each pig on a calibrated scale on Days −3, 24 and 49, or on the day that a pig was found dead after challenge. Body weights were recorded on the Body Weight Form. Day −3 body weights were utilized to block pigs prior to randomization. Day 24 and Day 49 weight data was utilized to deter-

mine the average daily weight gain (ADWG) for each pig during these time points. For pigs that died after challenge and before Day 49, the ADWG was adjusted to represent the ADWG from Day 24 to the day of death.

In order to determine PCV2 serology, venous whole blood was collected from each piglet from the orbital venous sinus on Days −3 and 14. For each piglet, blood was collected from the orbital venous sinus by inserting a sterile capillary tube into the medial canthus of one of the eyes and draining approximately 3.0 mL of whole blood into a 4.0 mL Serum Separator Tube (SST). On Days 24, 31, and 49, venous whole blood from each pig was collected from the anterior vena cava using a sterile 18 g×1½" Vacutainer needle (Becton Dickinson and Company, Franklin Lakes, N.J.), a Vacutainer needle holder and a 13 mL SST. Blood collections at each time point were recorded on the Sample Collection Record. Blood in each SST was allowed to clot, each SST was then spun down and the serum harvested. Harvested serum was transferred to a sterile snap tube and stored at −70±10° C. until tested at a later date. Serum samples were tested for the presence of PCV2 antibodies by BIVI-R&D personnel.

Pigs were observed once daily from Day 20 to Day 49 for clinical symptoms and clinical observations were recorded on the Clinical Observation Record.

To test for PCV2 nasal shedding, on Days 24, 25, and then every other odd numbered study day up to and including Day 49, a sterile dacron swab was inserted intra nasally into either the left or right nostril of each pig (one swab per pig) as aseptically as possible, swished around for a few seconds and then removed. Each swab was then placed into a single sterile snap-cap tube containing 1.0 mL of EMEM media with 2% IFBS, 500 units/mL of Penicillin, 500 μg/mL of Streptomycin and 2.5 μg/mL of Fungizone. The swab was broken off in the tube, and the snap tube was sealed and appropriately labeled with animal number, study number, date of collection, study day and "nasal swab." Sealed snap tubes were stored at −40±10° C. until transported overnight on ice to BIVI-St. Joseph. Nasal swab collections were recorded on the Nasal Swab Sample Collection Form. BIVI-R&D conducted quantitative virus isolation (VI) testing for PCV2 on nasal swab samples. The results were expressed in $\log_{10}$ values. A value of 1.3 logs or less was considered negative and any value greater than 1.3 logs was considered positive.

Pigs that died (Nos. 28, 52, 56, 69, 82, and 93) at the first study site were necropsied to the level necessary to determine a diagnosis. Gross lesions were recorded and no tissues were retained from these pigs. At the second study site, pigs that died prior to Day 49 (Nos. 45, 23, 58, 35), pigs found dead on Day 49 prior to euthanasia (Nos. 2, 43) and pigs euthanized on Day 49 were necropsied. Any gross lesions were noted and the percentages of lung lobes with lesions were recorded on the Necropsy Report Form.

From each of the 103 pigs necropsied at the second study site, a tissue sample of tonsil, lung, heart, liver, mesenteric lymph node, kidney and inguinal lymph node was placed into a single container with buffered 10% formalin; while another tissue sample from the same aforementioned organs was placed into a Whirl-pak (M-Tech Diagnostics Ltd., Thelwall, UK) and each Whirl-pak was placed on ice. Each container was properly labeled. Sample collections were recorded on the Necropsy Report Form. Afterwards, formalin-fixed tissue samples and a Diagnostic Request Form were submitted for IHC testing. IHC testing was conducted in accordance with standard ISU laboratory procedures for receiving samples, sample and slide preparation, and staining techniques. Fresh tissues in Whirl-paks were shipped with ice packs to the Study Monitor for storage (−70°±10° C.) and possible future use. Formalin-fixed tissues were examined by a pathologist for detection of PCV2 by IHC and scored using the following scoring system: 0=None; 1=Scant positive staining, few sites; 2=Moderate positive staining, multiple sites; and 3=Abundant positive staining, diffuse throughout the tissue. Due to the fact that the pathologist could not positively differentiate inguinal LN from mesenteric LN, results for these tissues were simply labeled as Lymph Node and the score given the highest score for each of the two tissues per animal.

Results

Results for this example are given below. It is noted that one pig from Group 9 died before Day 0, and 5 more pigs died post-vaccination (1 pig from Group 4; 1 pig from Group 6; 2 pigs from Group 8; and 1 pig from Group 9). Post-mortem examination indicated all six died due to underlying infections that were not associated with vaccination or PMWS. Additionally, no adverse events or injection site reactions were noted with any groups.

Average daily weight gain (ADWG) results are presented below in Table 6. Group 9, the strict negative control group, had the highest ADWG (1.06±0.17 lbs/day), followed by Group 5 (0.94±0.22 lbs/day), which received one dose of 8 μg of rORF2. Group 3, which received one dose of 4 μg of vORF2, had the lowest ADWG (0.49±0.21 lbs/day), followed by Group 7 (0.50±0.15 lbs/day), which received 2 doses of killed vaccine.

TABLE 6

Summary of Group Average Daily Weight Gain (ADWG)

Group	Treatment	N	ADWG - lbs/day (Day 24 to Day 49) or adjusted for pigs dead before Day 29
1	vORF2 - 16 μg (1 dose)	12	0.87 ± 0.29 lbs/day
2	vORF2 - 8 μg (1 dose)	12	0.70 ± 0.32 lbs/day
3	vORF2 - 4 μg (1 dose)	12	0.49 ± 0.21 lbs/day
4	rORF2 - 16 μg (1 dose)	11	0.84 ± 0.30 lbs/day
5	rORF2 - 8 μg (1 dose)	12	0.94 ± 0.22 lbs/day
6	rORF2 - 4 μg (1 dose)	11	0.72 ± 0.25 lbs/day
7	KV (2 doses)	12	0.50 ± 0.15 lbs/day
8	Challenge Controls	10	0.76 ± 0.19 lbs/day
9	Strict Negative Controls	11	1.06 ± 0.17 lbs/day

vORF2 = isolated viral ORF2;

rORF2 = recombinant baculovirus expressed ORF2;

killed whole cell virus = PCV2 virus grown in suitable cell culture

PCV2 serology results are presented below in Table 7. All nine groups were seronegative for PCV2 on Day −3. On Day 14, Groups receiving vORF2 vaccines had the highest titers, which ranged from 187.5 to 529.2. Pigs receiving killed viral vaccine had the next highest titers, followed by the groups receiving rORF2 vaccines. Groups 8 and 9 remained seronegative at this time. On Day 24 and Day 31, pigs receiving vORF2 vaccines continued to demonstrate a strong serological response, followed closely by the group that received two doses of a killed viral vaccine. Pigs receiving rORF2 vaccines were slower to respond serologically and Groups 8 and 9 continued to remain seronegative. On Day 49, pigs receiving vORF2 vaccine, 2 doses of the killed viral vaccine and the lowest dose of rORF2 demonstrated the strongest serological responses. Pigs receiving 16 μg and 8 μg of rORF2 vaccines had slightly higher IFA titers than challenge controls. Group 9 on Day 49 demonstrated a strong serological response.

TABLE 7

Summary of Group PCV2 IFA Titers
AVERAGE IFA TITER

Group	Treatment	Day −3	Day 14	Day 24	Day 31**	Day 49***
1	vORF2 - 16 μg (1 dose)	50.0	529.2	4400.0	7866.7	11054.5
2	vORF2 - 8 μg (1 dose)	50.0	500.0	3466.7	6800.0	10181.8
3	vORF2 - 4 μg (1 dose)	50.0	187.5	1133.3	5733.3	9333.3
4	rORF2 - 16 μg (1 dose)	50.0	95.5	1550.0	3090.9	8000.0
5	rORF2 - 8 μg (1 dose)	50.0	75.0	887.5	2266.7	7416.7
6	rORF2 - 4 μg (1 dose)	50.0	50.0	550.0	3118.2	10570.0
7	KV (2 doses)	50.0	204.2	3087.5	4620.8	8680.0
8	Challenge Controls	50.0	55.0	50.0	50.0	5433.3
9	Strict Negative Controls	50.0	59.1	59.1	54.5	6136.4

vORF2 = isolated viral ORF2;

rORF2 = recombinant baculovirus expressed ORF2;

killed whole cell virus = PCV2 virus grown in suitable cell culture

*For calculation purposes, a ≤ 100 IFA titer was designated as a titer of "50"; a ≥ 6400 IFA titer was designated as a titer of "12,800".

**Day of Challenge

***Day of Necropsy

The results from the post-challenge clinical observations are presented below in Table 8. This summary of results includes observations for Abnormal Behavior, Abnormal Respiration, Cough and Diarrhea. Table 9 includes the results from the Summary of Group Overall Incidence of Clinical Symptoms and Table 10 includes results from the Summary of Group Mortality Rates Post-challenge. The most common clinical symptom noted in this study was abnormal behavior, which was scored as mild to severe lethargy. Pigs receiving the 2 lower doses of vORF2, pigs receiving 16 μg of rORF2 and pigs receiving 2 doses of KV vaccine had incidence rates of ≥27.3%. Pigs receiving 8 μg of rORF2 and the strict negative control group had no abnormal behavior. None of the pigs in this study demonstrated any abnormal respiration. Coughing was noted frequently in all groups (0 to 25%), as was diarrhea (0-20%). None of the clinical symptoms noted were pathognomic for PMWS.

The overall incidence of clinical symptoms varied between groups. Groups receiving any of the vORF2 vaccines, the group receiving 16 μg of rORF2, the group receiving 2 doses of KV vaccine and the challenge control group had the highest incidence of overall clinical symptoms (≥36.4%). The strict negative control group, the group receiving 8 μg of rORF2 and the group receiving 4 μg of rORF2 had overall incidence rates of clinical symptoms of 0%, 8.3% and 9.1%, respectively.

Overall mortality rates between groups varied as well. The group receiving 2 doses of KV vaccine had the highest mortality rate (16.7%); while groups that received 4 μg of vORF2, 16 μg of rORF2, or 8 μg of rORF2 and the strict negative control group all had 0% mortality rates.

TABLE 8

Summary of Group Observations for Abnormal Behavior, Abnormal Respiration, Cough, and Diarrhea

Group	Treatment	N	Abnormal Behavior[1]	Abnormal Behavior[2]	Cough[3]	Diarrhea[4]
1	vORF2 - 16 μg (1 dose)	12	2/12 (16.7%	0/12 (0%)	3/12 (25%)	2/12 (16/7%)
2	vORF2 - 8 μg (1 dose)	12	4/12 (33.3%)	0/12 (0%)	1/12 (8.3%	1/12 (8.3%)
3	vORF2 - 4 μg (1 dose)	12	8/12 (66.7%)	0/12 (0%)	2/12 (16.7%)	1/12 (8.3%)
4	rORF2 - 16 μg (1 dose)	11	3/11 (27.3%)	0/11 (0%)	0/11 (0%)	2/11 (18.2%)
5	rORF2 - 8 μg (1 dose)	12	0/12 (0%)	0/12 (0%)	1/12 (8.3%)	0/12 (0%)
6	rORF2 - 4 μg (1 dose)	11	1/11 (9.1%)	0/11 (0%)	0/11 (0%)	0/12 (0%)
7	KV (2 doses)	12	7/12 (58.3)	0/12 (0%)	0/12 (0%)	1/12 (8.3%)
8	Challenge Controls	10	1/10 (10%)	0/10 (0%)	2/10 (20%)	2/10 (20%)
9	Strict Negative Controls	11	0/11 (0%)	0/11 (0%)	0/11 (0%)	0/11 (0%)

vORF2 = isolated viral ORF2;

rORF2 = recombinant baculovirus expressed ORF2;

killed whole cell virus = PCV2 virus grown in suitable cell culture

[1]Total number of pigs in each group that demonstrated any abnormal behavior for at least one day

[2]Total number of pigs in each group that demonstrated any abnormal respiration for at least one day

[3]Total number of pigs in each group that demonstrated a cough for at least one day

[4]Total number of pigs in each group that demonstrated diarrhea for at least one day

TABLE 9

Summary of Group Overall Incidence of Clinical Symptoms

Group	Treatment	N	Incidence of pigs with Clinical Symptoms[1]	Incidence Rate
1	vORF2 - 16 μg (1 dose)	12	5	41.7%
2	vORF2 - 8 μg (1 dose)	12	5	41.7%
3	vORF2 - 4 μg (1 dose)	12	8	66.7%
4	rORF2 - 16 μg (1 dose)	11	4	36.4%
5	rORF2 - 8 μg (1 dose)	12	1	8.3%
6	rORF2 - 4 μg (1 dose)	11	1	9.1%
7	KV (2 doses)	12	7	58.3%
8	Challenge Controls	10	4	40%
9	Strict Negative Controls	11	0	0%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
killed whole cell virus = PCV2 virus grown in suitable cell culture
[1]Total number of pigs in each group that demonstrated any clinical symptom for at least one day

TABLE 10

Summary of Group Mortality Rates Post-challenge

Group	Treatment	N	Dead Post-challenge	Mortality Rate
1	vORF2 - 16 μg (1 dose)	12	1	8.3%
2	vORF2 - 8 μg (1 dose)	12	1	8.3%
3	vORF2 - 4 μg (1 dose)	12	0	0%
4	rORF2 - 16 μg (1 dose)	11	0	0%
5	rORF2 - 8 μg (1 dose)	12	0	0%
6	rORF2 - 4 μg (1 dose)	11	1	9.1%
7	KV (2 doses)	12	2	16.7%
8	Challenge Controls	10	1	10%
9	Strict Negative Controls	11	0	0%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
killed whole cell virus = PCV2 virus grown in suitable cell culture

PCV2 nasal shedding results are presented below in Table 11. Following challenge on Day 24, 1 pig in Group 7 began shedding PCV2 on Day 27. None of the other groups experienced shedding until Day 33. The bulk of nasal shedding was noted from Day 35 to Day 45. Groups receiving any of the three vORF2 vaccines and groups receiving either 4 or 8 μg of rORF2 had the lowest incidence of nasal shedding of PCV2 (<9.1%). The challenge control group (Group 8) had the highest shedding rate (80%), followed by the strict negative control group (Group 9), which had an incidence rate of 63.6%.

TABLE 11

Summary of Group Incidence of Nasal Shedding of PCV2

Group	Treatment	N	No. Of pigs that shed for at least one day	Incidence Rate
1	vORF2 - 16 μg (1 dose)	12	1	8.3%
2	vORF2 - 8 μg (1 dose)	12	1	8.3%
3	vORF2 - 4 μg (1 dose)	12	1	8.3%
4	rORF2 - 16 μg (1 dose)	11	2	18.2%
5	rORF2 - 8 μg (1 dose)	12	1	8.3%
6	rORF2 - 4 μg (1 dose)	11	1	9.1%
7	KV (2 doses)	12	5	41.7%
8	Challenge Controls	10	8	80%
9	Strict Negative Controls	11	7	63.6%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
killed whole cell virus = PCV2 virus grown in suitable cell culture

The Summary of Group Incidence of Icterus, Group Incidence of Gastric Ulcers, Group Mean Lung Lesion Scores, and Group Incidence of Lung Lesions are shown below in Table 12. Six pigs died at the first test site during the post-vaccination phase of the study (Group 4, N=1; Group 6, N=1; Group 8, N=2; Group 9, N=2). Four out of six pigs had fibrinous lesions in one or more body cavities, one pig (Group 6) had lesions consistent with clostridial disease, and one pig (Group 9) had no gross lesions. None of the pigs that died during the post-vaccination phased of the study had lesions consistent with PMWS.

Pigs that died post-challenge and pigs euthanized on Day 49 were necropsied. At necropsy, icterus and gastric ulcers were not present in any group. With regard to mean % lung lesions, Group 9 had lowest mean % lung lesions (0%), followed by Group 1 with 0.40±0.50% and Group 5 with 0.68±1.15%. Groups 2, 3, 7 and 8 had the highest mean % lung lesions (≥7.27%). Each of these four groups contained one pig with % lung lesions≥71.5%, which skewed the results higher for these four groups. With the exception of Group 9 with 0% lung lesions noted, the remaining 8 groups had <36% lung lesions. Almost all lung lesions noted were described as red/purple and consolidated.

TABLE 12

Summary of Group Incidence of Icterus, Group Incidence of Gastric Ulcers, Group Mean % Lung Lesion Scores, and Group Incidence of Lung Lesions Noted

Group	Treatment	Icterus	Gastric Ulcers	Mean % Lung Lesions	Incidence of Lung Lesions Noted
1	vORF2 - 16 μg (1 dose)	0/12 (0%)	0/12 (0%)	0.40 ± 0.50%	10/12 (83%)
2	vORF2 - 8 μg (1 dose)	0/12 (0%)	0/12 (0%)	7.41 ± 20.2%	10/12 (83%)
3	vORF2 - 4 μg (1 dose)	0/12 (0%)	0/12 (0%)	9.20 ± 20.9%	10/12 (83%)
4	rORF2 - 16 μg (1 dose)	0/11 (0%)	0/11 (0%)	1.5 ± 4.74%	4/11 (36%)
5	rORF2 - 8 μg (1 dose)	0/12 (0%)	0/12 (0%)	0.68 ± 1.15%	9/12 (75%)
6	rORF2 - 4 μg (1 dose)	0/11 (0%)	0/11 (0%)	2.95 ± 5.12%	7/11 (64%)
7	KV (2 doses)	0/12 (0%)	0/12 (0%)	7.27 ± 22.9%	9/12 (75%)
8	Challenge Controls	0/10 (0%)	0/10 (0%)	9.88 ± 29.2%	8/10 (80%)

TABLE 12-continued

Summary of Group Incidence of Icterus, Group Incidence of Gastric Ulcers, Group Mean % Lung Lesion Scores, and Group Incidence of Lung Lesions Noted

Group	Treatment	Icterus	Gastric Ulcers	Mean % Lung Lesions	Incidence of Lung Lesions Noted
9	Strict Negative Controls	0/11 (0%)	0/11 (0%)	0/11 (0%)	0/11 (0%)

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

The Summary of Group IHC Positive Incidence Results are shown in Table 13. Group 1 (vORF2-16 μg) and Group 5 (rORF2-8 μg) had the lowest rate of IHC positive results (16.7%). Group 8 (Challenge Controls) and Group 9 (Strict Negative Controls) had the highest rate of IHC positive results, 90% and 90.9%, respectively.

TABLE 13

Summary of Group IHC Positive Incidence Rate

Group	Treatment	N	No. Of pigs that had at least one tissue positive for PCV2	Incidence Rate
1	vORF2 - 16 μg (1 dose)	12	2	16.7%
2	vORF2 - 8 μg (1 dose)	12	3	25.0%
3	vORF2 - 4 μg (1 dose)	12	8	66.7%
4	rORF2 - 16 μg (1 dose)	11	4	36.3%
5	rORF2 - 8 μg (1 dose)	12	2	16.7%
6	rORF2 - 4 μg (1 dose)	11	4	36.4%
7	KV (2 doses)	12	5	41.7%

TABLE 13-continued

Summary of Group IHC Positive Incidence Rate

Group	Treatment	N	No. Of pigs that had at least one tissue positive for PCV2	Incidence Rate
8	Challenge Controls	10	9	90.0%
9	Strict Negative Controls	11	10	90.9%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

Post-challenge, Group 5, which received one dose of 8 μg of rORF2 antigen, outperformed the other 6 vaccine groups. Group 5 had the highest ADWG (0.94±0.22 lbs/day), the lowest incidence of abnormal behavior (0%), the second lowest incidence of cough (8.3%), the lowest incidence of overall clinical symptoms (8.3%), the lowest mortality rate (0%), the lowest rate of nasal shedding of PCV2 (8.3%), the second lowest rate for mean % lung lesions (0.68±1.15%) and the lowest incidence rate for positive tissues (16.7%). Groups receiving various levels of rORF2 antigen overall outperformed groups receiving various levels of vORF2 and the group receiving 2 doses of killed whole cell PCV2 vaccine performed the worst. Tables 14 and 15 contain summaries of group post-challenge data.

TABLE 14

Summary of Group Post-Challenge Data - Part 1

Group	N	Treatment	ADWG (lbs/day)	Abnormal Behavior	Cough	Overall Incidence of Clinical Symptoms
1	12	vORF2 - 16 μg (1 dose)	0.87 ± 0.29	2/12 (16.7%)	3/12 (25%)	41.7%
2	12	vORF2 - 8 μg (1 dose)	0.70 ± 0.32	4/12 (33.3%	1/12 (8.3%	41.7%
3	12	vORF2 - 4 μg (1 dose)	0.49 ± 0.21	8/12 (66.7%)	2/12 (16.7%	66.7%
4	11	rORF2 - 16 μg (1 dose)	0.84 ± 0.30	3/11 (27.3%)	0/11 (0%)	36.4%
5	12	rORF2 - 8 μg (1 dose)	0.94 ± 0.22	0/12 (0%)	1/12 (8.3%	8.3%
6	11	rORF2 - 4 μg (1 dose)	0.72 ± 0.25	1/11 (9.1%	0/11 (0%)	9.1%
7	12	KV (2 doses)	0.50 ± 0.15	7/12 (58.3)	0/12 (0%)	58.3%
8	10	Challenge Controls	0.76 ± 0.19	1/10 (10%)	2/10 (20%	40%
9	11	Strict Negative Controls	1.06 ± 0.17	0/11 (0%)	0/11 (0%)	0%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

TABLE 15

Summary of Group Post-Challenge Data - Part 2

Group	N	Treatment	Mortality Rate	Nasal Shedding	Mean % Lung Lesions	Incidence Rate of at least one tissue IHC positive for PCV2
1	12	vORF2 - 16 μg (1 dose)	8.3%	8.3%	0.40 ± 0.50%	16.7%
2	12	vORF2- 8 μg (1 dose)	8.3%	8.3%	7.41 ± 20.2%	25.0%
3	12	vORF2 - 4 μg (1 dose)	0%	8.3%	9.20 ± 20.9%	66.7%
4	11	rORF2 - 16 μg (1 dose)	0%	18.2%	1.50 ± 4.74%	36.3%
5	12	rORF2 - 8 μg (1 dose)	0%	8.3%	0.68 ± 1.15%	16.7%
6	11	rORF2 - 4 μg (1 dose)	9.1%	9.1%	2.95 ± 5.12%	36.4%
7	12	KV (2 doses)	16.7%	41.7%	7.27 ± 22.9%	41.7%
8	10	Challenge Controls	10%	80%	9.88 ± 29.2%	90.0%
9	11	Strict Negative Controls	0%	63.6%	0/11 (0%)	90.9%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

Results of this study indicate that all further vaccine efforts should focus on a rORF2 vaccine. Overall, nasal shedding of PCV2 was detected post-challenge and vaccination with a PCV2 vaccine resulted in a reduction of shedding. Immunohistochemistry of selected lymphoid tissues also served as a good parameter for vaccine efficacy, whereas large differences in ADWG, clinical symptoms, and gross lesions were not detected between groups. This study was complicated by the fact that extraneous PCV2 was introduced at some point during the study, as evidenced by nasal shedding of PCV2, PCV2 seroconversion and positive IHC tissues in Group 9, the strict negative control group.

Discussion

Seven PCV2 vaccines were evaluated in this study, which included three different dose levels of vORF2 antigen administered once on Day 0, three different dose levels of rORF2 antigen administered once on Day 0 and one dose level of killed whole cell PCV2 vaccine administered on Day 0 and Day 14. Overall, Group 5, which received 1 dose of vaccine containing 8 μg of rORF2 antigen, had the best results. Group 5 had the highest ADWG, the lowest incidence of abnormal behavior, the lowest incidence of abnormal respiration, the second lowest incidence of cough, the lowest incidence of overall clinical symptoms, the lowest mortality rate, the lowest rate of nasal shedding of PCV2, the second lowest rate for mean % lung lesions and the lowest incidence rate for positive IHC tissues.

Interestingly, Group 4, which received a higher dose of rORF2 antigen than Group 5, did not perform as well or better than Group 5. Group 4 had a slightly lower ADWG, a higher incidence of abnormal behavior, a higher incidence of overall clinical symptoms, a higher rate of nasal shedding of PCV2, a higher mean % lung lesions, and a higher rate for positive IHC tissues than Group 5. Statistical analysis, which may have indicated that the differences between these two groups were not statistically significant, was not conducted on these data, but there was an observed trend that Group 4 did not perform as well as Group 5.

Post-vaccination, 6 pigs died at the first study site. Four of the six pigs were from Group 8 or Group 9, which received no vaccine. None of the six pigs demonstrated lesions consistent with PMWS, no adverse events were reported and overall, all seven vaccines appeared to be safe when administered to pigs approximately 11 days of age. During the post-vaccination phase of the study, pigs receiving either of three dose levels of vORF2 vaccine or killed whole cell vaccine had the highest IFAT levels, while Group 5 had the lowest IFAT levels just prior to challenge, of the vaccine groups.

Although not formally proven, the predominant route of transmission of PCV2 to young swine shortly after weaning is believed to be by oronasal direct contact and an efficacious vaccine that reduces nasal shedding of PCV2 in a production setting would help control the spread of infection. Groups receiving one of three vORF2 antigen levels and the group receiving 8 μg of rORF2 had the lowest incidence rate of nasal shedding of PCV2 (8.3%). Expectedly, the challenge control group had the highest incidence rate of nasal shedding (80%).

Gross lesions in pigs with PMWS secondary to PCV2 infection typically consist of generalized lymphadenopathy in combination with one or a multiple of the following: (1) interstitial pneumonia with interlobular edema, (2) cutaneous pallor or icterus, (3) mottled atrophic livers, (4) gastric ulcers and (5) nephritis. At necropsy, icterus, hepatitis, nephritis, and gastric ulcers were not noted in any groups and lymphadenopathy was not specifically examined for. The mean % lung lesion scores varied between groups. The group receiving 16 μg of vORF2 antigen had the lowest mean % lung lesion score (0.40±0.50%), followed by the group that received 8 μg of rORF2 (0.68±1.15%). As expected, the challenge control group had the highest mean % lung lesion score (9.88±29.2%). In all four groups, the mean % lung lesion scores were elevated due to one pig in each of these groups that had very high lung lesion scores. Most of the lung lesions were described as red/purple and consolidated. Typically, lung lesions associated with PMWS are described as tan and non-collapsible with interlobular edema. The lung lesions noted in this study were either not associated with PCV2 infection or a second pulmonary infectious agent may have been present. Within the context of this study, the % lung lesion scores probably do not reflect a true measure of the amount of lung infection due to PCV2.

Other researchers have demonstrated a direct correlation between the presence of PCV2 antigen by IHC and histopathology. Histopathology on select tissues was not conducted with this study. Group 1 (16 μg of vORF2) and Group 5 (8 μg of rORF2) had the lowest incidence rate of pigs positive for PCV2 antigen (8.3%), while Group 9 (the strict negative control group—90.9%) and Group 8 (the challenge control group –90.0%) had the highest incidence rates for pigs positive for PCV2 antigen. Due to the non-subjective nature of this test, IHC results are probably one of the best parameters to judge vaccine efficacy on.

Thus, in one aspect of the present invention, the Minimum Protective Dosage (MPD) of a 1 ml/1 dose recombinant product with extracted PCV2 ORF2 (rORF2) antigen in the CDCD pig model in the face of a PCV2 challenge was determined. Of the three groups that received varying levels of rORF2 antigen, Group 5 (8 μg of rORF2 antigen) clearly had the highest level of protection. Group 5 either had the best results or was tied for the most favorable results with regard to all of the parameters examined. When Group 5 was compared with the other six vaccine groups post-challenge, Group 5 had the highest ADWG (0.94±0.22 lbs/day), the lowest incidence

of abnormal behavior (0%), the second lowest incidence of cough (8.3%), the lowest incidence of overall clinical symptoms (8.3%), the lowest mortality rate (0%), the lowest rate of nasal shedding of PCV2 (8.3%), the second lowest rate for mean % lung lesions (0.68±1.15%) and the lowest incidence rate for positive IHC tissues (16.7%).

In another aspect of the present invention, the MPD of a 1 ml/1 dose conventional product that is partially purified PCV2 ORF2 (vORF2) antigen in the CDCD pig model in the face of a PCV2 challenge was determined. Of the three groups that received varying levels of vORF2 antigen, Group 1 (16 μg of vORF2) had the highest level of protection. Group 1 outperformed Groups 2 and 3 with respect to ADWG, mean % lung lesions, and IHC. Groups 1 and 2 (8 μg of vORF2 antigen) performed equally with respect to overall incidence of clinical symptoms, Group 3 (4 μg of vORF2 antigen) had the lowest mortality rate, and all three groups performed equally with respect to nasal shedding. Overall, vORF vaccines did not perform as well as rORF vaccines.

In yet another aspect of the present invention, the efficacy of a maximum dose of a 2 ml/2 dose Conventional Killed PCV2 vaccine in the CDCD pig model in the face of a PCV2 challenge was determined. Of the seven vaccines evaluated in this study, the killed whole cell PCV2 vaccine performed the worst. Piglets receiving two doses of killed whole cell PCV2 vaccine had the lowest ADWG, the second highest rate of abnormal behavior (58.3%), the second highest overall incidence of clinical symptoms (58.3%), the highest mortality rate (16.7%), the second highest incidence of nasal shedding (41.7%), highest mean % lung lesions (9.88±29.2%), a high incidence of lung lesions noted (75%) and a moderate IHC incidence rate in tissues (41.7%). However, it was still effective at invoking an immune response.

In still another aspect of the present invention, nasal shedding of PCV2 was assessed as an efficacy parameter and the previous PCV2 efficacy parameters from previous studies were reconfirmed. Results from this study indicate that nasal shedding of PCV2 occurs following intra nasal challenge and that PCV2 vaccines reduce nasal shedding of PCV2 post-challenge. Furthermore, results from this study and reports in the literature indicate that IHC should continue to be evaluated in future PCV2 vaccine trials as well.

Some additional conclusions arising from this study are that lymphadenopathy is one of the hallmarks of PMWS. Another one of the hallmarks of PMWS is lymphoid depletion and multinucleated/giant histiocytes. Additionally, no adverse events or injection site reactions were noted for any of the 7 PCV2 vaccines and all 7 PCV2 vaccines appeared to be safe when administered to young pigs.

EXAMPLE 5

This example tests the efficacy of eight PCV2 candidate vaccines and reconfirms PCV2 challenge parameters from earlier challenge studies following exposure to a virulent strain of PCV2. One hundred and fifty (150) cesarean derived colostrum deprived (CDCD) piglets, 6-16 days of age, were blocked by weight and randomly divided into 10 groups of equal size. Table 16 sets forth the General Study Design for this Example.

TABLE 16

General Study Design

Group	No. Of Pigs	Treatment	Day of Treatment	KLH/ICFA on Day 22 and Day 28	Challenge with Virulent PCV2 on Day 25	PRRSV MLV on Day 46	Necropsy on Day 50
1	15	PVC2 Vaccine 1 16 μg rORF2 - IMS 1314	0 & 14	+	+	+	+
2	15	PVC2 Vaccine 2 16 μg vORF2 - Carbopol	0 & 14	+	+	+	+
3	15	PCV2 Vaccine 3 16 μg rORF2 - Carbopol	0 & 14	+	+	+	+
4	15	PCV2 Vaccine 2 16 μg vORF2 - Carbopol	0	+	+	+	+
5	15	PVC2 Vaccine 3 4 μg rORF2 - Carbopol	0 & 14	+	+	+	+
6	15	PVC2 Vaccine 3 1 μg rORF2 - Carbopol	0 & 14	+	+	+	+
7	15	PVC2 Vaccine 3 0.25 μg rORF2 - Carbopol	0 & 14	+	+	+	+
8	15	PVC2 Vaccine 4 >8.0 log KV - Carbopol	0 & 14	+	+	+	+
9	15	Challenge Controls	N/A	+	+	+	+
10	15	None - Strict Negative Control Group	N/A	+	–	+	+

vORF2 = isolated viral ORF2;

rORF2 = recombinant baculovirus expressed ORF2;

KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

The vaccine formulation given to each group was as follows. PCV2 Vaccine No. 1, administered at 1×2 ml dose to Group 1, was a high dose (16 ug/2 ml dose) of inactivated recombinant ORF2 antigen adjuvanted with IMS 1314 (16 ug rORF2—IMS 1314). PCV2 Vaccine No. 2, administered at 1×2 ml dose to Group 2, was a high dose (16 ug/2 ml dose) of a partially purified VIDO R-1 generated PCV2 ORF2 antigen adjuvanted with Carbopol (16 ug vORF2—Carbopol). PCV2 Vaccine No. 3, administered at 1×2 ml dose to Group 3, was a high dose (16 ug/2 ml dose) of inactivated recombinant ORF2 antigen adjuvanted with Carbopol (16 ug rORF2—Carbopol). PCV2 Vaccine No. 4, administered at 1×1 ml dose to Group 4, was a high dose (16 ug/1 ml dose) of a partially purified VIDO R-1 generated PCV2 ORF2 antigen adjuvanted with Carbopol (16 ug vORF2—Carbopol). Vaccine No. 5, administered at 1×2 ml dose to Group 5, was a 4 ug/2 ml dose of an inactivated recombinant ORF2 antigen adjuvanted with Carbopol (4 ug rORF2—Carbopol). PCV2 Vaccine No. 6, administered at 1×2 ml dose to Group 6, was a 1 ug/2 ml dose of an inactivated recombinant ORF2 antigen adjuvanted with Carbopol (1 ug rORF2—Carbopol). PCV2 Vaccine No. 7, administered at 1×2 ml dose to Group 7, was a low dose (0.25 ug/2 ml dose) of inactivated recombinant ORF2 antigen adjuvanted with Carbopol (0.25 ug rORF2—Carbopol). PCV2 Vaccine No. 8, administered at 1×2 ml dose to Group 8, was a high dose (pre-inactivation titer>8.0 log/2 ml dose) Inactivated Conventional Killed VIDO R-1 generated PCV2 Struve antigen adjuvanted with Carbopol (>8.0 log KV—Carbopol). On Day 0, Groups 1-8 were treated with their assigned vaccines. Groups 1-3 and 5-8 received boosters of their respective vaccines again on Day 14. The effectiveness of a single dose of 16 μg of vORF2—Carbopol was tested on Group 4 which did not receive a booster on Day 14. Piglets were observed for adverse events and injection site reactions following both vaccinations. On Day 21 the piglets were moved to a second study site where Groups 1-9 were group housed in one building and Group 10 was housed in a separate building. All pigs received keyhole limpet hemocyanin emulsified with incomplete Freund's adjuvant (KLH/ICFA) on Days 22 and 28. On Day 25, Groups 1-9 were challenged with approximately 4 logs of virulent PCV2 virus. By Day 46, very few deaths had occurred in the challenge control group. In an attempt to immunostimulate the pigs and increase the virulence of the PCV2 challenge material, all Groups were treated with INGELVAC® PRRSV MLV (Porcine Reproductive and Respiratory Vaccine, Modified Live Virus) on Day 46.

Pre- and post-challenge blood samples were collected for PCV2 serology. Post-challenge, body weight data for determination of average daily weight gain (ADWG) and observations of clinical signs were collected. On Day 50, all surviving pigs were necropsied, gross lesions were recorded, lungs were scored for pathology, and selected tissues were preserved in formalin for examination by Immunohistochemistry (IHC) for detection of PCV2 antigen at a later date.

Materials and Methods

This was a partially-blind vaccination-challenge feasibility study conducted in CDCD pigs, 6 to 16 days of age on Day 0. To be included in the study, PCV2 IFA titers of sows were ≤1:1000. Additionally, the serologic status of sows were from a known PRRS-negative herd. Sixteen (16) sows were tested for PCV2 serological status and all sixteen (16) had a PCV2 titer of ≤1000 and were transferred to the first study site. One hundred fifty (150) piglets were delivered by cesarean section surgeries and were available for this study on Day −3. On Day −3, 150 CDCD pigs at the first study site were weighed, identified with ear tags, blocked by weight and randomly assigned to 1 of 10 groups, as set forth above in table 16. Blood samples were collected from all pigs. If any test animal meeting the inclusion criteria was enrolled in the study and was later excluded for any reason, the Investigator and Monitor consulted in order to determine the use of data collected from the animal in the final analysis. The date of which enrolled piglets were excluded and the reason for exclusion was documented. No sows meeting the inclusion criteria, selected for the study and transported to the first study site were excluded. No piglets were excluded from the study, and no test animals were removed from the study prior to termination. Table 17 describes the time frames for the key activities of this Example.

TABLE 17

Study Activities

Study Day	Actual Dates	Study Activity
−3	Apr. 04, 2003	Weighed pigs; health exam; randomized to groups; collected blood samples
−3,	Apr. 04, 2003	
0-21	Apr. 07, 2003 to May 27, 2003	Observed for overall health and for adverse events post-vaccination
0	Apr. 07, 2003	Administered respective IVPs to Groups 1-8
0-7	Apr. 07, 2003 to Apr. 14, 2003	Observed pigs for injection site reactions
14	Apr. 21, 2003	Boostered Groups 1-3, 5-8 with respective IVPs; blood sampled all pigs
14-21	Apr. 21, 2003 to Apr. 28, 2003	Observed pigs for injection reactions
19-21	Apr. 26, 2003 to Apr. 28, 2003	Treated all pigs with antibiotics
21	Apr. 28, 2003	Pigs transported from Struve Labs, Inc. to Veterinary Resources, Inc.(VRI)
22-50	Apr. 28, 2003 to May 27, 2003	Observed pigs for clinical signs post-challenge
22	Apr. 29, 2003	Treated Groups 1-10 with KLH/ICFA
25	May 02, 2003	Collected blood samples from all pigs; weighed all pigs; challenged Groups 1-9 with PCV2 challenge material
28	May 05, 2003	Treated Groups 1-10 with KLH/ICFA
32	May 09, 2003	Collected blood samples from all pigs
46	May 23, 2003	Administered INGELVAC ® PRRS MLV to all groups

TABLE 17-continued

Study Activities		
Study Day	Actual Dates	Study Activity
50	May 27, 2003	Collected blood samples, weighed and necropsied all pigs; gross lesions were recorded; lungs were evaluated for lesions; fresh and formalin fixed tissue samples were saved; In-life phase of the study was completed

Following completion of the in-life phase of the study, formalin fixed tissues were examined by Immunohistochemistry (IHC) for detection of PCV2 antigen by a pathologist, blood samples were evaluated for PCV2 serology, and average daily weight gain (ADWG) was determined from Day 25 to Day 50.

Animals were housed at the first study site in individual cages in seven rooms from birth to approximately 11 days of age (approximately Day 0 of the study). Each room was identical in layout and consisted of stacked individual stainless steel cages with heated and filtered air supplied separately to each isolation unit. Each room had separate heat and ventilation, thereby preventing cross-contamination of air between rooms. Animals were housed in two different buildings at the second study site. Group 10 (The Strict negative control group) was housed separately in a converted nursery building and Groups 1-9 were housed in a converted farrowing building. Each group was housed in a separate pen (14-15 pigs per pen) and each pen provided approximately 2.3 square feet per pig. Groups 2, 4 and 8 were penned in three adjacent pens on one side of the alleyway and Groups 1, 3, 5, 6, 7, and 9 were penned in six adjacent pens on the other side of the alleyway. The Group separation was due to concern by the Study Monitor that vaccines administered to Groups 2, 4, and 8 had not been fully inactivated. Each pen was on an elevated deck with plastic slatted floors. A pit below the pens served as a holding tank for excrement and waste. Each building had its own separate heating and ventilation systems, with little likelihood of cross-contamination of air between buildings.

At the first study site, piglets were fed a specially formulated milk ration from birth to approximately 3 weeks of age. All piglets were consuming solid, special mixed ration by Day 21 (approximately 4½ weeks of age). At the second study site, all piglets were fed a custom non-medicated commercial mix ration appropriate for their age and weight, ad libitum. Water at both study sites was also available ad libitum. All test pigs were treated with 1.0 mL of NAXCEL®, IM, in alternating hams on Days 19, 20, and 21. In addition, Pig No. 11 (Group 1) was treated with 0.5 mL of NAXCEL® IM on Day 10, Pig No. 13 (Group 10) was treated with 1 mL of Penicillin and 1 mL of PREDEF® 2X on Day 10, Pig No. 4 (Group 9) was treated with 1.0 mL of NAXCEL® IM on Day 11, and Pigs 1 (Group 1), 4 and 11 were each treated with 1.0 mL of NAXCEL® on Day 14 for various health reasons.

While at both study sites, pigs were under veterinary care. Animal health examinations were conducted on Day −3 and were recorded on the Health Examination Record Form. All animals were in good health and nutritional status before vaccination as determined by observation on Day 0. All test animals were observed to be in good health and nutritional status prior to challenge. Carcasses and tissues were disposed of by rendering. Final disposition of study animals was recorded on the Animal Disposition Record.

On Days 0 and 14, pigs assigned to Groups 1-3 and 5-8 received 2.0 mL of assigned PCV2 Vaccines 1-4, respectively, IM in the right and left neck region, respectively, using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×½" needle. Pigs assigned to Group 4 received 1.0 mL of PCV2 Vaccine No. 2, IM in the right neck region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×½" needle on Day 0 only.

On Day 22 all test pigs received 2.0 mL of KLH/ICFA IM in the left neck region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×1" needle. On Day 28 all test pigs received 2.0 mL of KLH/ICFA in the right ham region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×1" needle.

On Day 25, pigs assigned to Groups 1-9 received 1.0 mL of PCV2 ISUVDL challenge material (3.98 $\log_{10}$ $TCID_{50}$/mL) IM in the right neck region using a sterile 3.0 mL Luer-lock syringe and a sterile 20 g×1" needle. An additional 1.0 mL of the same material was administered IN to each pig (0.5 mL per nostril) using a sterile 3.0 mL Luer-lock syringe and nasal canula.

On Day 46, all test pigs received 2.0 mL INGELVAC® PRRS MLV, IM, in the right neck region using a sterile 3.0 mL Luer0lock syringe and a sterile 20 g×1" needle. The PRRSV MLV was administered in an attempt to increase virulence of the PCV2 challenge material.

Test pigs were observed daily for overall health and adverse events on Day −3 and from Day 0 to Day 21. Each of the pigs was scored for normal or abnormal behavior, respiration or cough. Observations were recorded on the Clinical Observation Record. All test pigs were observed from Day 0 to Day 7, and Group 7 was further observed from Day 14 to 21, for injection site reactions. Average daily weight gain was determined by weighing each pig on a calibrated scale on Days −3, 25 and 50, or on the day that a pig was found dead after challenge. Body weights were recorded on the Body Weight Form. Day −3 body weights were utilized to block pigs prior to randomization. Day 25 and Day 50 weight data was utilized to determine the average daily weight gain (ADWG) for each pig during these time points. For pigs that died after challenge and before Day 50, the ADWG was adjusted to represent the ADWG from Day 25 to the day of death.

In order to determine PCV2 serology, venous whole blood was collected from each piglet from the orbital venous sinus on Days −3 and 14. For each piglet, blood was collected from the orbital venous sinus by inserting a sterile capillary tube into the medial canthus of one of the eyes and draining approximately 3.0 mL of whole blood into a 4.0 mL Serum Separator Tube (SST). On Days 25, 32, and 50, venous whole blood from each pig was collected from the anterior vena cava using a sterile 20 g×1½" Vacutainer® needle (Becton Dickinson and Company, Franklin Lakes, N.J.), a Vaccutainer® needle holder and a 13 mL SST. Blood collections at each time point were recorded on the Sample Collection Record. Blood in each SST was allowed to clot, each SST was then spun down and the serum harvested. Harvested serum was transferred to a sterile snap tube and stored at −70±10° C. until tested at a later date. Serum samples were tested for the presence of PCV2 antibodies by BIVI-R&D personnel.

Pigs were observed once daily from Day 22 to Day 50 for clinical symptoms and scored for normal or abnormal behavior, respiration or cough. Clinical observations were recorded on the Clinical Observation Record.

Pigs Nos. 46 (Group 1) and 98 (Groups 9) died at the first study site. Both of these deaths were categorized as bleeding deaths and necropsies were not conducted on these two pigs. At the second study site, pigs that died after challenge and prior to Day 50, and pigs euthanized on Day 50, were necropsied. Any gross lesions were noted and the percentages of lung lobes with lesions were recorded on the Necropsy Report Form.

From each of the pigs necropsied at the second study site, a tissue sample of tonsil, lung, heart, and mesenteric lymph node was placed into a single container with buffered 10% formalin; while another tissue sample from the same aforementioned organs was placed into a Whirl-pak® (M-Tech Diagnostics Ltd., Thelwall, UK) and each Whirl-pak® was placed on ice. Each container was properly labeled. Sample collections were recorded on the Necropsy Report Form. Afterwards, formalin-fixed tissue samples and a Diagnostic Request Form were submitted for IHC testing. IHC testing was conducted in accordance with standard laboratory procedures for receiving samples, sample and slide preparation, and staining techniques. Fresh tissues in Whirl-paks® were shipped with ice packs to the Study Monitor for storage (−70°±10° C.) and possible future use.

Formalin-fixed tissues were examined by a pathologist for detection of PCV2 by IHC and scored using the following scoring system: 0=None; 1=Scant positive staining, few sites; 2=Moderate positive staining, multiple sites; and 3=Abundant positive staining, diffuse throughout the tissue. For analytical purposes, a score of 0 was considered "negative," and a score of greater than 0 was considered "positive."

Results

Results for this example are given below. It is noted that Pigs No. 46 and 98 died on days 14 and 25 respectively. These deaths were categorized as bleeding deaths. Pig No. 11 (Group 1) was panting with rapid respiration on Day 15. Otherwise, all pigs were normal for behavior, respiration and cough during this observation period and no systemic adverse events were noted with any groups. No injection site reactions were noted following vaccination on Day 0. Following vaccination on Day 14, seven (7) out of fourteen (14) Group 1 pigs (50.0%) had swelling with a score of "2" on Day 15. Four (4) out of fourteen (14) Group 1 (28.6%) still had a swelling of "2" on Day 16. None of the other groups experienced injection site reactions following either vaccination.

Average daily weight gain (ADWG) results are presented below in Table 18. Pigs No. 46 and 98 that died from bleeding were excluded from group results. Group 4, which received one dose of 16 ug vORF2—Carbopol, had the highest ADWG (1.16±0.26 lbs/day), followed by Groups 1, 2, 3, 5, 6, and 10 which had ADWGs that ranged from 1.07±0.23 lbs/day to 1.11±0.26 lbs/day. Group 9 had the lowest ADWG (0.88±0.29 lbs/day), followed by Groups 8 and 7, which had ADWGs of 0.93±0.33 lbs/day and 0.99±0.44 lbs/day, respectively.

TABLE 18

Summary of Group Average Daily Weight Gains (ADWG)

Group	Treatment	N	ADWG - lbs/day (Day 25 to Day 50) or adjusted for pigs dead before Day 50
1	rORF2 - 16 μg - IMS 1314 2 doses	14	1.08 ± 0.30 lbs/day
2	vORF2 - 16 μg - Carbopol 2 doses	15	1.11 ± 0.16 lbs/day
3	rORF2 - 16 μg - Carbopol 2 doses	15	1.07 ± 0.21 lbs/day
4	vORF2 - 16 μg - Carbopol 1 dose	15	1.16 ± 0.26 lbs/day
5	rORF2 - 4 μg - Carbopol 1 dose	15	1.07 ± 0.26 lbs/day
6	rORF2 - 1 μg - Carbopol 2 doses	15	1.11 ± 0.26 lbs/day
7	rORF2 - 0.25 μg - Carbopol 2 doses	15	0.99 ± 0.44 lbs/day
8	KV > 8.0 log - Carbopol 2 doses	15	0.93 ± 0.33 lbs/day
9	Challenge Controls	14	0.88 ± 0.29 lbs/day
10	Strict Negative Controls	15	1.07 ± 0.23 lbs/day

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

PVC2 serology results are presented below in Table 19. All ten (10) groups were seronegative for PCV2 on Day −3. On Day 14, PCV2 titers remained low for all ten (10) groups (range of 50-113). On Day 25, Group 8, which received the whole cell killed virus vaccine, had the highest PCV2 titer (4617), followed by Group 2, which received 16 ug vORF2—Carbopol, Group 4, which received as single dose of 16 ug vORF2—Carbopol, and Group 3, which received 16 ug rORF2—Carbopol, which had titers of 2507, 1920 and 1503 respectively. On Day 32 (one week post challenge), titers for Groups 1-6 and Group 8 ranged from 2360 to 7619; while Groups 7 (0.25 ug rORF2—Carbopol), 9 (Challenge Control), and 10 (Strict negative control) had titers of 382, 129 and 78 respectively. On Day 50 (day of necropsy), all ten (10) groups demonstrated high PCV2 titers (≥1257).

On Days 25, 32, and 50, Group 3, which received two doses of 16 ug rORF2—Carbopol had higher antibody titers than Group 1, which received two doses of 16 ug rORF2—IMS 1314. On Days 25, 32 and 50, Group 2, which received two doses of 16 ug vORF2 had higher titers than Group 4, which received only one does of the same vaccine. Groups 3, 5, 6, 7, which received decreasing levels of rORF2—Carbopol, of 16, 4, 1, and 0.25 ug respectively, demonstrated correspondingly decreasing antibody titers on Days 25 and 32.

TABLE 19

Summary of Group PCV2 IFA Titers

Group	Treatment	Day −3	Day 14**	Day 25***	Day 32	Day 50****
1	rORF2 - 16 μg - IMS 1314 2 doses	50	64	646	3326	4314
2	vORF2 - 16 μg - Carbopol 2 doses	50	110	2507	5627	4005
3	rORF2 - 16 μg - Carbopol 2 doses	50	80	1503	5120	6720
4	vORF2 - 16 μg - Carbopol 1 dose	50	113	1920	3720	1257
5	rORF2 - 4 μg - Carbopol 1 dose	50	61	1867	3933	4533

TABLE 19-continued

Summary of Group PCV2 IFA Titers

Group	Treatment	Day −3	Day 14**	Day 25***	Day 32	Day 50****
6	rORF2 - 1 μg - Carbopol 2 doses	50	70	490	2360	5740
7	rORF2 - 0.25 μg - Carbopol 2 doses	50	73	63	382	5819
8	KV > 8.0 log - Carbopol 2 doses	50	97	4617	7619	10817
9	Challenge Controls	50	53	50	129	4288
10	Strict Negative Controls	50	50	50	78	11205

vORF2 = isolated viral ORF2;

rORF2 = recombinant baculovirus expressed ORF2;

KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

*For calculation purposes, a ≤ 100 IFA titer was designated as a titer of "50"; a ≥ 6400 IFA titer was designated as a titer of "12,800".

**Day of Challenge

***Day of Necropsy

The results from the post-challenge clinical observations are presented below. Table 20 includes observations for Abnormal Behavior, Abnormal Respiration, Cough and Diarrhea. Table 21 includes the results from the Summary of Group Overall Incidence of Clinical Symptoms and Table 22 includes results from the Summary of Group Mortality Rates Post-challenge. The incidence of abnormal behavior, respiration and cough post-challenge were low in pigs receiving 16 ug rORF2—IMS 1314 (Group 1), 16 ug rORF2—Carbopol (Group 3), 1 ug rORF2—Carbopol (Group 6), 0.25 ug rORF2—Carbopol (Group 7), and in pigs in the Challenge Control Group (Group 9). The incidence of abnormal behavior respiration and cough post-challenge was zero in pigs receiving 16 ug vORF2—Carbopol (Group 2), a single dose of 16 ug vORF2—Carbopol (Group 4), 4 ug rORF2—Carbopol (Group 5), >8 log KV—Carbopol (Group 8), and in pigs in the strict negative control group (Group 10).

The overall incidence of clinical symptoms varied between groups. Pigs receiving 16 ug vORF2—Carbopol (Group 2), a single dose of 16 ug vORF2—Carbopol (Group 4), and pigs in the Strict negative control group (Group 10) had incidence rates of 0%; pigs receiving 16 ug rORF2—Carbopol (Group 3), and 1 ug rORF2—Carbopol (Group 6) had incidence rates of 6.7%; pigs receiving 16 ug rORF2—IMS 1314 (Group 1) had an overall incidence rate of 7.1%; pigs receiving 4 ug rORF2—Carbopol (Group 5), 0.25 ug rORF2—Carbopol (Group 7), and >8 log KV vaccine had incidence rates of 13.3%; and pigs in the Challenge Control Group (Group 9) had an incidence rate of 14.3%.

Overall mortality rates between groups varied as well. Group 8, which received 2 doses of KV vaccine had the highest mortality rate of 20.0%; followed by Group 9, the challenge control group, and Group 7, which received 0.25 ug rORF2—Carbopol and had mortality rates of 14.3% and 13.3% respectively. Group 4, which received one dose of 16 ug vORF2—Carbopol had a 6.7% mortality rate. All of the other Groups, 1, 2, 3, 5, 6, and 10 had a 0% mortality rate.

TABLE 20

Summary of Group Observations for Abnormal Behavior, Abnormal Respiration, and Cough Post-Challenge

Group	Treatment	N	Abnormal Behavior[1]	Abnormal Behavior[2]	Cough[3]
1	rORF2 - 16 μg - IMS 1314 2 doses	14	0/14 (0%)	0/14 (0%)	1/14 (7.1%)
2	vORF2 - 16 μg - Carbopol 2 doses	15	0/15 (0%)	0/15 (0%)	0/15 (0%)
3	rORF2 - 16 μg - Carbopol 2 doses	15	0/15 (0%)	0/15 (0%)	1/15 (6.7%)
4	vORF2 - 16 μg - Carbopol 1 dose	15	0/15 (0%)	0/15 (0%)	0/15 (0%)
5	rORF2 - 4 μg - Carbopol 1 dose	15	1/15 (6.7%)	1/15 (6.7%)	0/15 (0%)
6	rORF2 - 1 μg - Carbopol 2 doses	15	0/15 (0%)	0/15 (0%)	1/15 (6.7%)
7	rORF2 - 0.25 μg - Carbopol 2 doses	15	0/15 (0%)	1/15 (6.7%)	1/15 (06.7%)
8	KV > 8.0 log - Carbopol 2 doses	15	1/15 (6.7%)	1/15 (6.7%)	0/15 (0%)
9	Challenge Controls	14	1/14 (7.1%)	1/14 (7.1%)	2/14 (14/3%)
10	Strict Negative Controls	15	0/15 (0%)	0/15 (0%)	0/15 (0%)

[1]Total number of pigs in each group that demonstrated any abnormal behavior for at least one day

[2]Total number of pigs in each group that demonstrated any abnormal respiration for at least one day

[3]Total number of pigs in each group that demonstrated a cough for at least one day

TABLE 21

Summary of Group Overall Incidence of Clinical Symptoms Post-Challenge

Group	Treatment	N	Incidence of pigs with Clinical Symptoms[1]	Incidence Rate
1	rORF2 - 16 μg - IMS 1314 2 doses	14	1	7.1%
2	vORF2 - 16 μg - Carbopol 2 doses	15	0	0.0%
3	rORF2 - 16 μg - Carbopol 2 doses	15	1	6.7%
4	vORF2 - 16 μg - Carbopol 1 dose	15	0	0.0%
5	rORF2 - 4 μg - Carbopol 1 dose	15	2	13.3%
6	rORF2 - 1 μg - Carbopol 2 doses	15	1	6.7%
7	rORF2 - 0.25 μg - Carbopol 2 doses	15	2	13.3%
8	KV > 8.0 log - Carbopol 2 doses	15	2	13.3%

TABLE 21-continued

Summary of Group Overall Incidence of Clinical Symptoms Post-Challenge

Group	Treatment	N	Incidence of pigs with Clinical Symptoms[1]	Incidence Rate
9	Challenge Controls	14	2	14.3%
10	Strict Negative Controls	15	0	0.0%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture
[1]Total number of pigs in each group that demonstrated any clinical symptom for at least one day

TABLE 22

Summary of Group Mortality Rates Post-Challenge

Group	Treatment	N	Dead Post-challenge	Mortality Rate
1	rORF2 - 16 μg - IMS 1314 2 doses	14	0	0.0%
2	vORF2 - 16 μg - Carbopol 2 doses	15	0	0.0%
3	rORF2 - 16 μg - Carbopol 2 doses	15	0	0.0%
4	vORF2 - 16 μg - Carbopol 1 dose	15	1	6.7%
5	rORF2 - 4 μg - Carbopol 1 dose	15	0	0.0%
6	rORF2 - 1 μg - Carbopol 2 doses	15	0	0.0%
7	rORF2 - 0.25 μg - Carbopol 2 doses	15	2	13.3%
8	KV > 8.0 log - Carbopol 2 doses	15	3	20.0%
9	Challenge Controls	14	2	14.3%
10	Strict Negative Controls	15	0	0.0%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

The Summary of Group Mean Percentage Lung Lesions and Tentative Diagnosis is given below in Table 23. Group 9, the challenge control group, had the highest percentage lung lesions with a mean of 10.81±23.27%, followed by Group 7, which received 0.25 ug rORF2—Carbopol and had a mean of 6.57±24.74%, Group 5, which received 4 ug rORF2—Carbopol and had a mean of 2.88±8.88%, and Group 8, which received the KV vaccine and had a mean of 2.01±4.98%. The remaining six (6) groups had lower mean percentage lung lesions that ranged from 0.11±0.38% to 0.90±0.15%.

Tentative diagnosis of pneumonia varied among the groups. Group 3, which received two doses of 16 ug rORF2—Carbopol, had the lowest tentative diagnosis of pneumonia, with 13.3%. Group 9, the challenge control group, had 50% of the group tentatively diagnosed with pneumonia, followed by Group 10, the strict negative control group and Group 2, which received two doses of 16 ug vORF2—Carbopol, with 46.7% of 40% respectively, tentatively diagnosed with pneumonia.

Groups 1, 2, 3, 5, 9, and 10 had 0% of the group tentatively diagnosed as PCV2 infected; while Group 8, which received two doses if KV vaccine, had the highest group rate of tentative diagnosis of PCV2 infection, which 20%. Group 7, which received two doses of 0.25 ug rORF2—Carbopol, and Group 4, which received one dose of 16 ug vORF2—Carbopol had tentative group diagnoses of PCV2 infection in 13.3% and 6.7% of each group, respectively.

Gastric ulcers were only diagnosed in one pig in Group 7 (6.7%); while the other 9 groups remained free of gastric ulcers.

TABLE 23

Summary of Group Mean % Lung Lesion and Tentative Diagnosis

Group	Treatment	N	No. Of pigs that shed for at least one day	Incidence Rate
1	rORF2 - 16 μg - IMS 1314 2 doses	15	0	0%
2	vORF2 - 16 μg - Carbopol 2 doses	15	1	6.7%
3	rORF2 - 16 μg - Carbopol 2 doses	15	3	20.0%
4	vORF2 - 16 μg - Carbopol 1 dose	15	2	13.3%
5	rORF2 - 4 μg - Carbopol 1 dose	15	3	20.0%
6	rORF2 - 1 μg - Carbopol 2 doses	15	6	40.0%
7	rORF2 - 0.25 μg - Carbopol 2 doses	15	7	46.7%
8	KV > 8.0 log - Carbopol 2 doses	15	12	80%
9	Challenge Controls	14	14	100.0%
10	Strict Negative Controls	15	14	93.3%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

The Summary of Group IHC Positive Incidence Results are shown below in Table 24. Group 1 (16 ug rORF2—IMS 1314) had the lowest group rate of IHC positive results with 0% of the pigs positive for PCV2, followed by Group 2 (16 ug vORF2—Carbopol) and Group 4 (single dose 16 ug vORF2—Carbopol), which had group IHC rates of 6.7% and 13.3% respectively. Group 9, the challenge control group, had the highest IHC positive incidence rate with 100% of the pigs positive for PCV2, followed by Group 10, the strict negative control group, and Group 8 (KV vaccine), with 93.3% and 80% of the pigs positive for PCV2, respectively.

TABLE 24

Summary of Group IHC Positive Incidence Rate

Group	Treatment	N	No. Of pigs that shed for at least one day	Incidence Rate
1	rORF2 - 16 μg - IMS 1314 2 doses	15	0	0%
2	vORF2 - 16 μg - Carbopol 2 doses	15	1	6.7%
3	rORF2 - 16 μg - Carbopol 2 doses	15	3	20.0%
4	vORF2 - 16 μg - Carbopol 1 dose	15	2	13.3%
5	rORF2 - 4 μg - Carbopol 1 dose	15	3	20.0%
6	rORF2 - 1 μg - Carbopol 2 doses	15	6	40.0%
7	rORF2 - 0.25 μg - Carbopol 2 doses	15	7	46.7%
8	KV > 8.0 log - Carbopol 2 doses	15	12	80%
9	Challenge Controls	14	14	100.0%
10	Strict Negative Controls	15	14	93.3%

vORF2 = isolated viral ORF2;
rORF2 = recombinant baculovirus expressed ORF2;
KV or killed whole cell virus = PCV2 virus grown in suitable cell culture

Discussion

Seven PCV2 vaccines were evaluated in this example, which included a high dose (16 μg) of rORF2 antigen adjuvanted with IMS 1314 administered twice, a high dose (16 μg) of vORF2 antigen adjuvanted with Carbopol administered once to one group of pigs and twice to a second group of pigs, a high dose (16 μg) of rORF2 antigen adjuvanted with Carbopol administered twice, a 4 μg dose of rORF2 antigen adjuvanted with Carbopol administered twice, a 1 μg dose of rORF2 antigen adjuvanted with Carbopol administered twice, a low dose (0.25 μg) of rORF2 antigen adjuvanted with Carbopol administered twice, and a high dose (>8 log) of killed whole cell PCV2 vaccine adjuvanted with Carbopol. Overall, Group 1, which received two doses of 16 μg rORF2—IMS 1314, performed slightly better than Groups 2 through 7, which received vaccines containing various levels of either vORF2 or rORF2 antigen adjuvanted with Carbopol and much better than Group 8, which received two doses of killed whole cell PCV2 vaccine. Group 1 had the third highest ADWG (1.80±0.30 lbs/day), the lowest incidence of abnormal behavior (0%), the lowest incidence of abnormal respiration (0%), a low incidence of cough (7.1%), a low incidence of overall clinical symptoms (7.1%), was tied with three other groups for the lowest mortality rate (0%), the second lowest rate for mean % lung lesions (0.15±0.34%), the second lowest rate for pneumonia (21.4%) and the lowest incidence rate for positive IHC tissues (0%). Group 1 was, however, the only group in which injection site reactions were noted, which included 50% of the vaccinates 1 day after the second vaccination. The other vaccines administered to Groups 2 through 7 performed better than the killed vaccine and nearly as well as the vaccine administered to Group 1.

Group 8, which received two doses of killed PCV2 vaccine adjuvanted with Carbopol, had the worst set of results for any vaccine group. Group 8 had the lowest ADWG (0.93±0.33 lbs/day), the second highest rate of abnormal behavior (6.7%), the highest rate of abnormal respiration (6.7%), was tied with three other groups for the highest overall incidence rate of clinical symptoms (13.3%), had the highest mortality rate of all groups (20%), and had the highest positive IHC rate (80%) of any vaccine group. There was concern that the killed whole cell PCV2 vaccine may not have been fully inactivated prior to administration to Group 8, which may explain this group's poor results. Unfortunately, definitive data was not available to confirm this concern. Overall, in the context of this example, a Conventional Killed PCV2 vaccine did not aid in the reduction of PCV2 associated disease.

As previously mentioned, no adverse events were associated with the test vaccines with exception of the vaccine adjuvanted with IMS 1314. Injection site reactions were noted in 50.0% of the pigs 1 day after the second vaccination with the vaccine formulated with IMS 1314 and in 28.6% of the pigs 2 days after the second vaccination. No reactions were noted in any pigs receiving Carbopol adjuvanted vaccines. Any further studies that include pigs vaccinated with IMS 1314 adjuvanted vaccines should continue to closely monitor pigs for injection site reactions.

All pigs were sero-negative for PCV2 on Day −3 and only Group 2 had a titer above 100 on Day 14. On Day 25 (day of challenge), Group 8 had the highest PCV2 antibody titer (4619), followed by Group 2 (2507). With the exception of Groups 7, 9 and 10, all groups demonstrated a strong antibody response by Day 32. By Day 50, all groups including Groups 7, 9 and 10 demonstrated a strong antibody response.

One of the hallmarks of late stage PCV2 infection and subsequent PMWS development is growth retardation in weaned pigs, and in severe cases, weight loss is noted. Average daily weight gain of groups is a quantitative method of demonstrating growth retardation or weight loss. In this example, there was not a large difference in ADWG between groups. Group 8 had the lowest ADWG of 0.88±0.29 lbs/day, while Group 4 had the highest ADWG of 1.16±0.26 lb/day. Within the context of this study there was not a sufficient difference between groups to base future vaccine efficacy on ADWG.

In addition to weight loss—dyspnea, lethargy, pallor of the skin and sometimes icterus are clinical symptoms associated with PMWS. In this example, abnormal behavior and abnormal respiration and cough were noted infrequently for each group. As evidenced in this study, this challenge model and challenge strain do not result in overwhelming clinical symptoms and this is not a strong parameter on which to base vaccine efficacy.

Overall, mortality rates were not high in this example and the lack of a high mortality rate in the challenge control group limits this parameter on which to base vaccine efficacy.

Prior to Day 46, Groups 4 and 7 each had one out of fifteen pigs die, Group 9 had two out of fourteen pigs die and Group 8 had three out of fifteen pigs die. Due to the fact that Group 9, the challenge control group was not demonstrating PCV2 clinical symptoms and only two deaths had occurred in this group by Day 46, Porcine Respiratory and Reproductive Syndrome Virus (PRRSV) MLV vaccine was administered to all pigs on Day 46. Earlier studies had utilized INGELVAC® PRRS MLV as an immunostimulant to exasperate PCV2-associated PMWS disease and mortality rates were higher in these earlier studies. Two deaths occurred shortly after administering the PRRS vaccine on Day 46—Group 4 had one death on Day 46 and Group 7 had one death on Day 47—which were probably not associated with the administration of the PRRS vaccine. By Day 50, Group 8, which received two doses of killed vaccine, had the highest mortality rate (20%), followed by Group 9 (challenge control) and Group 7 (0.25 ug rORF2—Carbopol), with mortality rates of 14.3% and 13.3% respectively. Overall, administration of the PRRS vaccine to the challenge model late in the post-challenge observation phase of this example did not significantly increase mortality rates.

Gross lesions in pigs with PMWS secondary to PCV2 infection typically consist of generalized lymphadenopathy in combination with one or more of the following: (1) interstitial pneumonia with interlobular edema, (2) cutaneous pallor or icterus, (3) mottled atrophic livers, (4) gastric ulcers and (5) nephritis. At necropsy (Day 50), icterus, hepatitis, and nephritis were not noted in any groups. A gastric ulcer was noted in one Group 7 pig, but lymphadenopathy was not specifically examined for. Based on the presence of lesions that were consistent with PCV2 infection, three groups had at least one pig tentatively diagnosed with PCV2 (PMWS). Group 8, which received two doses of killed vaccine, had 20% tentatively diagnosed with PCV2, while Group 7 and Group 4 had 13.3% and 6.7%, respectively, tentatively diagnosed with PCV2. The mean % lung lesion scores varied between groups at necropsy. Groups 1, 2, 3, 4, 6 and 10 had low % lung lesion scores that ranged from 0.11±0.38% to 0.90±0.15%. As expected, Group 9, the challenge control group, had the highest mean % lung lesion score (10.81±23.27%). In four groups, the mean % lung lesion scores were elevated due to one to three pigs in each of these groups having very high lung lesion scores. The lung lesions were red/purple and consolidated. Typically, lung lesions associated with PMWS are described as tan, non-collapsible with interlobular edema. The lung lesions noted in this study were either not associated with PCV2 infection or a second pulmonary infectious agent may have been present. Within the context of this study, the % lung

lesion scores probably do not reflect a true measure of the amount of lung infection due to PCV2. Likewise, tentative diagnosis of pneumonia may have been over-utilized as well. Any pigs with lung lesions, some as small as 0.10% were listed with a tentative diagnosis of pneumonia. In this example, there was no sufficient difference between groups with respect to gross lesions and % lung lesions on which to base vaccine efficacy.

IHC results showed the largest differences between groups. Group 1 (16 μg rORF2—IMS 1314) had the lowest positive IHC results for PCV2 antigen (0%); while Groups 9 and 10 had the highest positive IHC results with incidence rates of 100% and 93.3% respectively. Groups 3, 5, 6 and 7, which received 16, 4, 1 or 0.25 μg of rORF2 antigen, respectively, adjuvanted with Carbopol, had IHC positive rates of 20%, 20%, 40% and 46.7%, respectively. Group 2, which received two doses of 16 μg vORF2 adjuvanted with Carbopol had an IHC positive rate of 6.7%, while Group 4 which received only one dose of the same vaccine, had an IHC positive rate of 13.3%. Due to the objective nature of this test and the fact that IHC results correlated with expected results, IHC testing is probably one of the best parameters on which to base vaccine efficacy.

Thus in one aspect of the present invention, the Minimum Protective Dosage (MPD) of PCV2 rORF2 antigen adjuvanted with Carbopol in the CDCD pig model in the face of a PCV2 challenge is determined Groups 3, 5, 6 and 7 each received two doses of rORF2 antigen adjuvanted with Carbopol, but the level of rORF2 antigen varied for each group. Groups 3, 5, 6 and 7 each received 16, 4, 1 or 0.25 μg of rORF2 antigen respectively. In general, decreasing the level of rORF2 antigen decreased PCV2 antibody titers, and increased the mortality rate, mean % lung lesions and the incidence of IHC positive tissues. Of the four groups receiving varying levels of rORF2—Carbopol, Groups 3 and 5, which received two doses of 16 or 4 μg of rORF2 antigen, respectively, each had an IHC positive rate of only 20%, and each had similar antibody titers. Overall, based on IHC positive results, the minimum protective dosage of rORF2 antigen administered twice is approximately 4 μg.

In another aspect of the present invention, the antigenicity of recombinant (rORF2) and VIDO R-1 (vORF2) PCV2 antigens were assessed. Group 2 received two doses of 16 μg vORF2 and Group 3 received two doses of 16 μg rORF2. Both vaccines were adjuvanted with Carbopol. Both vaccines were found to be safe and both had 0% mortality rate. Group 2 had a PCV2 antibody titer of 2507 on Day 25, while Group 3 had a PCV2 antibody titer of 1503. Group 3 had a lower mean % lung lesion score than Group 2 (0.11±0.38% vs. 0.90±0.15%), but Group 2 had a lower IHC positive incidence rate that Group 3 (6.7% vs. 20%). Overall, both vaccines had similar antigenicity, but vORF2 was associated with slightly better IHC results.

In yet another aspect of the present invention, the suitability of two different adjuvants (Carbopol and IMS 1314) was determined Groups 1 and 3 both received two doses of vaccine containing 16 ug of rORF2 antigen, but Group 1 received the antigen adjuvanted with IMS 1314 while Group 3 received the antigen adjuvanted with Carbopol. Both groups had essentially the same ADWG, essentially the same incidence of clinical signs post-challenge, the same mortality rate, and essentially the same mean % lung lesions; but Group 1 had an IHC positive rate of 0% while Group 3 had an IHC positive rate of 20%. However, Group 3, which received the vaccine adjuvanted with Carbopol had higher IFAT PCV2 titers on Days 25, 32 and 50 than Group 1, which received the vaccine adjuvanted with IMS 1314. Overall, although the PCV2 vaccine adjuvanted with IMS 1314 did provide better IHC results, it did not provide overwhelmingly better protection from PCV2 infection and did induce injection site reaction. Whereas the PCV2 vaccine adjuvanted with Carbopol performed nearly as well as the IMS 1314 adjuvanted vaccine, but was not associated with any adverse events.

In still another aspect of the present invention, the feasibility of PCV2 ORF2 as a 1 ml, 1 dose product was determined Groups 2 and 4 both received 16 μg of vORF2 vaccine adjuvanted with Carbopol on Day 0, but Group 2 received a second dose on Day 14. Group 4 had a slightly higher ADWG and a lower mean % lung lesions than Group 2, but Group 2 had higher IFAT PCV2 titers on Day 25, 32 and 50, and a slightly lower incidence rate of IHC positive tissues. All other results for these two groups were similar. Overall, one dose of vORF2 adjuvanted with Carbopol performed similar to two doses of the same vaccine.

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<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: This is a modified Kozak's sequence

<400> SEQUENCE: 1

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<210> SEQ ID NO 2
<211> LENGTH: 6
<212> TYPE: DNA
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20 25 30

Arg His Arg Tyr Arg Trp Arg Arg Lys Asn Gly Ile Phe Asn Thr Arg

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Pro Ser Trp Ala Val Asp Met Met Arg Phe Asn Ile Asp Asp Phe Val
65                  70                  75                  80

Pro Pro Gly Gly Gly Thr Asn Lys Ile Ser Ile Pro Phe Glu Tyr Tyr
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Arg Ile Arg Lys Val Lys Val Glu Phe Trp Pro Cys Ser Pro Ile Thr
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Gln Gly Asp Arg Gly Val Gly Ser Thr Ala Val Ile Leu Asp Asp Asn
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Phe Val Thr Lys Ala Thr Ala Leu Thr Tyr Asp Pro Tyr Val Asn Tyr
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Ser Ser Arg His Thr Ile Pro Gln Pro Phe Ser Tyr His Ser Arg Tyr
145                 150                 155                 160

Phe Thr Pro Lys Pro Val Leu Asp Ser Thr Ile Asp Tyr Phe Gln Pro
                165                 170                 175

Asn Asn Lys Arg Asn Gln Leu Trp Leu Arg Leu Gln Thr Ser Arg Asn
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Val Asp His Val Gly Leu Gly Thr Ala Phe Glu Asn Ser Lys Tyr Asp
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Arg His Arg Tyr Arg Trp Arg Arg Lys Asn Gly Ile Phe Asn Thr Arg
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Pro Ser Trp Ala Val Asp Met Met Arg Phe Asn Ile Asp Asp Phe Val
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Pro Pro Gly Gly Gly Thr Asn Lys Ile Ser Ile Pro Phe Glu Tyr Tyr
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Arg Ile Arg Lys Val Lys Val Glu Phe Trp Pro Cys Ser Pro Ile Thr
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Gln Gly Asp Arg Gly Val Gly Ser Thr Ala Val Ile Leu Asp Asp Asn
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Phe Val Thr Lys Ala Thr Ala Leu Thr Tyr Asp Pro Tyr Val Asn Tyr
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Ser Ser Arg His Thr Ile Pro Gln Pro Phe Ser Tyr His Ser Arg Tyr
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Phe Thr Pro Lys Pro Val Leu Asp Ser Thr Ile Asp Tyr Phe Gln Pro
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Val Asp His Val Gly Leu Gly Thr Ala Phe Glu Asn Ser Lys Tyr Asp
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<223> OTHER INFORMATION: This sequence is from porcine circovirus type 2, open reading frame 2, together with a portion from the pGEM T-easy vector.

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<223> OTHER INFORMATION: This is the porcine circovirus type 2, ORF2 construct, which includes baculovirus and pGEM T-easy coding sequences.

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Thr Leu Ser


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Arg His Arg Tyr Arg Trp Arg Arg Lys Asn Gly Ile Phe Asn Thr Arg
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Pro Ser Trp Ala Val Asp Met Met Arg Phe Asn Ile Asp Asp Phe Val
65                  70                  75                  80

Pro Pro Gly Gly Gly Thr Asn Lys Ile Ser Ile Pro Phe Glu Tyr Tyr
                85                  90                  95

Arg Ile Lys Lys Val Lys Val Glu Phe Trp Pro Cys Ser Pro Ile Thr
            100                 105                 110

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Phe Val Thr Lys Ala Thr Ala Leu Thr Tyr Asp Pro Tyr Val Asn Tyr
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Asn Leu Lys Asp Pro Pro Leu Lys Pro
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```

We claim:

1. A single dose multivalent combination vaccine comprising:

4 μg to 400 μg of recombinant PCV2 ORF2 protein per dose;

at least one pharmaceutically acceptable carrier selected from the group consisting of: effective amount of antimicrobial active agent, or an effective amount of a stabilizing agent that increases the shelf-life of the vaccine;

and at least one immunogenic active component against *Mycoplasma hyopneumoniae*, Porcine Reproductive and Respiratory Syndrome Virus (PRRSV), or a combination thereof,

wherein said vaccine provides protective immunity and is effective for lessening the severity of against one or more clinical symptoms associated with PCV2 infection after the administration of a single dose of said vaccine, compared to those swine not receiving said vaccine and wherein said one or more clinical symptoms are selected from the group consisting of wasting, paleness of the skin, unthriftiness, respiratory distress, diarrhea, icterus, jaundice, lung lesions, nasal shedding, cough, diarrhea and combinations thereof, wherein said recombinant PCV2 ORF2 protein is selected from the group consisting of:

i) a polypeptide selected from the group consisting of SEQ ID NO: 5, SEQ ID NO: 6, and SEQ ID NO: 11;

ii) a PCV2 ORF2 polypeptide that is at least 90% identical to any polypeptide of i); or

iii) a polypeptide that is encoded by a DNA comprising the sequence of SEQ ID NO: 3 or SEQ ID NO: 4.

2. The single dose multivalent combination vaccine of claim **1**, wherein said vaccine comprises recombinant PCV2 ORF2 protein further comprises an additional component selected from the group consisting of an inactivated viral vector, cell culture supernate, BEI, sodium thiosulfate, carriers, adjuvants, media, viral inactivators, diluents, isotonic agents, immunomodulatory agents, antibiotics, pharmaceutical acceptable salts, and combinations thereof.

3. The single dose multivalent combination vaccine of claim **1**, wherein one dose of said single dose vaccine has a volume of at least 1 ml.

4. The single dose multivalent combination vaccine of claim **1**, wherein one dose of said vaccine has a volume of 2 ml.

5. The single dose multivalent combination vaccine of claim **1**, wherein said vaccine is retained within a container.

6. The single dose multivalent combination vaccine of claim **1**, wherein said further immunogenic active component is *Mycoplasma hyopneumoniae.*

7. The single dose multivalent combination vaccine of claim **1**, wherein said further immunogenic active component is PRRSV.

8. The single dose multivalent combination vaccine of claim **1**, wherein said further immunogenic active components are *Mycoplasma hyopneumoniae* and PRRSV.

9. The single dose multivalent combination vaccine of claim **7**, wherein said vaccine comprises 3-10 logs of PRRSV.

10. The single dose multivalent combination vaccine of claim **7**, wherein said vaccine additionally comprises a PRRSV antigen.

11. The single dose multivalent combination vaccine of claim **1**, wherein the amount of PCV2 ORF2 protein in said vaccine is 4 μg to 200 μg per dose.

* * * * *